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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF GLASGOW.

VOL. X.

1892-96.

GLASGOW: PUBLISHED BY THE SOCIETY,
AT ITS ROOMS, 207 BATH STREET.

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JAMES BARCLAY MURDOCH, F.R.Ph.S.E.

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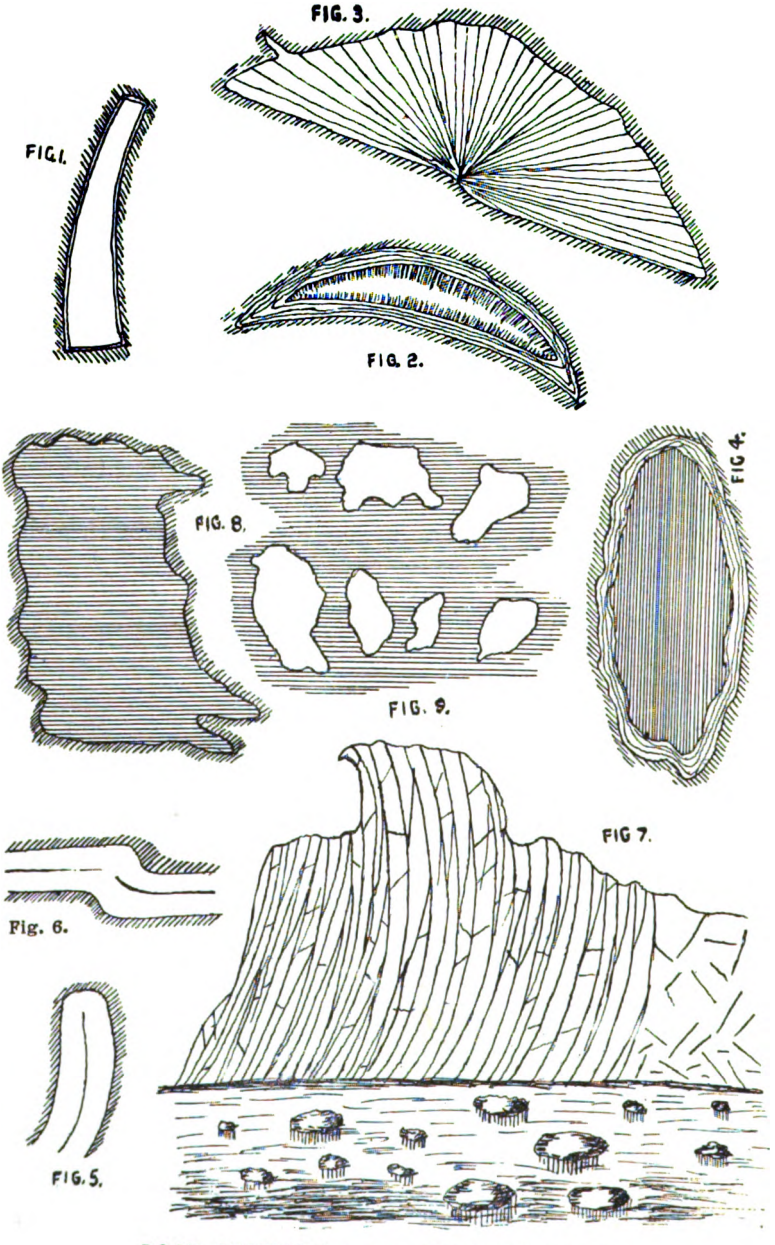

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. I.—From the Doon to the Girvan Water, along the Carrick Shore. By John Smith. With Illustrations [Plate I.], and a Coast Section.

[Read 18th October, 1892.]

The town of Ayr is situated on a piece of flat, low-lying, sandy ground, and a considerable area in the neighbourhood is of much the same description. Immediately the Doon is crossed the surface begins to rise, and continues to do so until it culminates in Brown Carrick Hill, 940 feet above sea-level. This hill only towards its summit still answers to its colour name, which, no doubt, before cultivation had crept so far up its sides, was even more appropriate. About three-quarters of a mile to the south of the lowest Doon Bridge, is the old quarry of Burnside, at one time worked for limestone, until the "tir" became too heavy; not that it is very thick, but that it consists, where I examined it, of 5 feet of flinty chert. This chert is of a peculiar quality, being lightish-coloured, with numerous small cavities bristling with minute quartz crystals; but neither in it, nor in the underlying light-grey limestone, which is in parts crystalline, have I detected any fossils, although I have visited the locality several times.

In Burnside quarry grows in some profusion the Potato-flowered Bitter-sweet, and in an adjacent cornfield the Poor man's Weather-glass has its beautiful crimson flowers wide open; the latter we take as a happy omen for a good day in which to accomplish the long walk that is before us, and when night comes we find that we have not been disappointed. In a cultivated field near by we get

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the rather scarce Buxbaum's Speedwell, and the Long Smooth-headed Poppy, and passing along by the side of a wet ditch we find the rather rare and very elegant Great Water Horse-tail, the largest native species of the order to which it belongs. By the roadside the Imperforate St. John's-Wort is in good flower, and near it is the Barren Brome-grass. On the sea-shore we find the Rest Harrow, which we observe in favourable spots, and often in abundance, all the way to Girvan.

The first rock we meet on the shore is dark soft trap, at the rifle gangway, and reaching Greenan Castle we find it to be situated on top of a small cliff of greenish, rather fine-grained volcanic ash, stratified, and with a few stones. On a grassy bank beside the Castle is the very rare Soft-Knotted Trefoil, the flowers just withered, and, along the sea margin, abundance of the Lady's-Bedstraw in good flower. The Purple Sea-Rocket is observed here and there amongst the bent and the higher shingle, and further along specimens with white flowers were obtained.

Between Greenan Castle and the Heads of Ayr the tide sweeps over strata of the cementstone group, made up of fine-grained grey layers of cement, and grey shaley beds with grey sandy plies, all dipping at a gentle angle towards the town of Ayr. In the former we find the bivalve cases of ostracods, in the latter, plant-roots and traces of other vegetation, and *Spirorbis;* fragments of scorpions have also been found in them. Cutting through these beds several dolerite dykes run seawards, two of them being known by the names of the "Deil's Dyke" and "Long Rae." About five hundred yards south of the castle is a dyke, in the centre of which is to be seen a small patch of the stratified measures lying as nearly as possible in the normal position.

The east end of the Heads of Ayr having been reached the cementstone beds are seen in a very small section nearly in a vertical position, and lying close up against the tuff which forms the Heads of Ayr, and part of the shore in this locality. Here are a number of boulders, most of them having been formed out of the tuff, but a few from a distance. At no point do we see the cement beds going under the tuff, but embedded in the latter are many bits of the cement limestone, amongst them on the shore being a piece 2 feet by 2 feet by 10 inches thick, in which are a few fish scales. Bits of limestone got in the tuff often show no

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fossils, but such is not the case with this fragment, and the question is whether it has been tossed as a bomb out of a volcano, or brought to its position by other agencies. Its angles are not much worn, but many of the limestone pebbles in the tuff are well rounded.

The Heads of Ayr, which rise to, perhaps, 300 feet, are in a very decaying state, and their base towards the sea is covered with a grass-grown talus. At their western end the outcropping edges of volcanic ashbeds are seen sweeping in a curve of large radius away out to sea, and strongly suggest the idea that we have before us a section of the sloping side of a volcanic-ash cone. Whether this is so or not, the original angle of stratification must have been considerably altered, as it is now seen to vary from about 70 degrees to a nearly vertical position, which originally, under any circumstance, it could not possibly have done. The ash at the west part of the Heads is much more stony than that at Greenan Castle, though probably of the same age.

Turning the Heads we are immediately in view of a splendid patch of the Bloody Crane's-bill, and the steep rocks gives place to a long bracken-covered slope, which extends to about 200 yards beyond Brackenbrae Cot. The shore here is strewn with boulders of grey and reddish granite, probably transported from the Loch Doon district; and mixed with them are traps and a few North Highland schists. At the south end of this slope the calciferous sandstone suddenly appears, at once forming considerable cliffs, and shewing that this alteration has been brought about by a fault. The calciferous beds are here built up of conglomerates, of a reddish colour towards the base, the contained pebbles being mostly quartz and quartzite—none of very large size—with smaller ones of red jasper and lydian stone. There is much current-bedding, but the main bedding-planes are seen to lie almost horizontally. The top portion of the cliffs is of sandstone, which weathers to a reddish and whitish colour, the latter predominating, and on the rocks here and there the Wall Pennywort is at the present time in flower.

In these sandstone cliffs there are two sets of caves. The first, and the most numerous, are just above present high-tide level, the second set being situated some ten feet higher. Through the cliffs run two dolerite dykes, which pass out to sea, and towards their south-western extremity the cliffs rise to a vertical height of about 100 feet.

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Appended to his "Old Red Sandstone," seventh edition, at page 365, in an article on "The Fossiliferous Deposits of Scotland," Hugh Miller says that "vast numbers" [of *Pterichthys major*] "have recently been found, though in a broken state, in the Upper Old Red Sandstone of the 'Heads of Ayr.'" We presume this refers to the calciferous beds just described, as what we know as the "Heads of Ayr" are made up of agglomerates. Opposite Lagg the calciferous beds are suddenly cut off by a fault, and are succeeded by much higher cliffs of porphyrite. On these grow numerous specimens of the Rose-root, now past flowering, though in some instances we mistake the coloured carpels for flowers.

The porphyrite cliffs at this part are about 150 feet in height, and weather to a dull liver colour, though a fresh fracture shows the rock to be greyish, compact, with felspar and a few small roundish agates here and there. The shore gravel, derived from the local rocks, also contains agates, and some one has even thought it worth while to blast the rock for them. In Lagg quarry, on the roadside, about half a mile from the shore, numerous agates have been got; and when I visited it about three years ago I saw sections of specimens 36 inches in length by 12 inches at the thickest part, with the agate only round the sides from 1 to 3 inches thick, the interior space being filled with quartz, some of it of amethystine colour, and some cavities in the quartz containing a quantity of dark brown powder (wad?). Besides the long oval cavities there was one curved (see Plate I., fig. 1), 17 inches long by $2\frac{1}{2}$ inches thick at one end and 1 inch at the other—the colour of the agate being amethyst and white. Another cavity was crescent-shaped (fig. 2), 23 inches long and $4\frac{1}{2}$ inches across at the thickest part. This agate was bluish round the edges, and had the centre filled with crystallized quartz.

At this part of the shore the cliffs cease for a short distance, and on a grassy slope there is a large patch in flower of the Hemlock Water-Dropwort. We note here, in the shore gravel, chalk flints, which are also to be found at many other parts of it. Having passed from the shore up to Braehead, the porphyrite is seen to take more of a purple colour, and the rock contains a larger quantity of felspar crystals. Hollows which have been filled with salt water and evaporated to dryness are seen covered

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with minute salt crystals. Turning a corner to the left we see a bed of coarse agglomerate, under the porphyrite, and dipping towards the sea. Though only 6 feet are seen, it is probably much thicker, and is composed of pebbles of ash, felstone, and amygdaloidal trap. At this point a small patch of sandstone is interstratified with the porphyrite.

For about 500 yards to the north-east of the road which leads from the shore up to Drumbane, a bit of the old beach, which the present tide has not yet managed to carve away, still remains. We now return to the old sea-cliff, which here has got a grass-covered talus. In the rocks at the shore is a cavity 8 feet long by 3 feet 4 inches at its widest part, one side being nearly straight and the other one curved like a bow. This cavity is filled with white calcite, slightly tinged with red, and from a point near the centre of the straight side, the divisional planes of calcite crystals radiate towards every part of the curved side (Plate I., fig. 3). We pass a sea-stack about 16 feet by 12, and soon reach another one at the foot of an old road, 30 feet by 20; by the side of it are several calcite veins in the porphyrite.

The cliffs are now much lower; the porphyrite contains a large quantity of green earth with abundance of felspar crystals, many of them arranged in those curious starry clusters so peculiar to this kind of rock, and many gas cavities are filled with crystallized calcite. On the top of these cliffs, especially where there is not much soil, the Vernal Squill grows, and, as it flowers early, we find some of its seeds already ripe.

On the shore, at several parts, we passed over green "meadows" of the Grass Wrack, on which innumerable Periwinkles were feeding, and at one part of the cliffs we noted the Lesser Meadow-Rue, a very rare Ayrshire plant, and a single patch of the Honeysuckle. The Scottish Lovage was frequently seen; the Hemp-Agrimony, and the Mugwort, were not uncommon, but not yet in flower. Foxgloves seemed to be scarce, but Harebells and Wild Thyme were abundant.

About a mile to the north of Dunure, the porphyrite is again seen to contain a few agates, and we note some peculiarly horizontally-banded varieties. They generally have a thin coating of agate around the interior of the cavities, the rest of the banding being horizontal (fig. 4), and generally of a light colour. In

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specimens which have been much decomposed by weathering, the layers of these varieties can easily be separated, and are then seen to be white and chalky. On the shore, passing through the porphyrite, we have seen occasional creamy-white or very pale red bands up to 6 inches wide. They look like veins of "white horse" whinstone, but are not veins at all, and simply arise from the decomposition and discolouration of the porphyrite. In the centre of these vein-like masses is seen a line, which is an original joint in the porphyrite, and from both sides of it the decomposition has started. We come to a very interesting one, where the joint has not run into the side of another joint, but has terminated in the solid rock, and the decomposed vein-like part, which is 2½ inches wide, also terminates about an inch beyond the joint (Plate I., fig. 5). In these altered parts of the rock the amygdaloidal cavities are mostly found to be empty, and though the felspar is much altered it still occupies its place.

A little nearer Dunure the porphyrite is very compact, and is purplish in colour, glittering where washed by the tide. Some of it is very much jointed, the joints running through it in every direction, and is duller in colour, without the glitter. At several places we noted thin veins filled with impure agate, but here some of the agate veins were comparatively pure, and whatever might be the colour of the centre, those we examined, at least, began with a thin red layer on each side. One we observed, an inch thick, is at a certain point of double thickness (fig. 6), but we think the crack must have been of this form before the agate was filled into it.

There are here a number of sea-stacks, and one of them, about 20 feet high, shows the rock-jointings running in a very peculiar curving manner (fig. 7).

After passing some low-tide rocks covered with *Balani*, we arrive at Dunure fishing village, situated almost on the sea-shore, and well sheltered by the rising ground to the east. By the road-side, close to Dunure, or "Port Rorie" as it is sometimes called, lies a thick bed of green conglomerate, some of the pebbles in it reaching a diameter of over a foot. At the old castle of Dunure, which stands on a cliff overhanging the sea, the rocks contain agates, some of them of considerable size, and much the same in character as those in Lagg quarry.

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In this immediate neighbourhood are some curious infillings in the porphyrite. We have observed this peculiar deposit in cavities all along the coast, but not nearly to such an extent as here, and it occurs further along wherever these rocks are exposed. The Geological Survey Officers (in the "Explanation" to Sheet 14) thus describe them and the cavities which contain them:— "Throughout the porphyrites of this group, irregular vertical veins of sandstone traverse the rocks in a stellar arrangement. The sandstone is horizontally stratified, and agrees in character with the sandstone lying between the porphyrites; whence it appears that these veins are due to the sand which was washed into the irregular star-shaped cracks of the cooled lava, before the lava was covered by the next stream of molten matter."

I had observed these peculiar infillings before I had read the Geological Survey explanation of the occurrence, and even when I had read it I was rather sceptical as to its validity. However, after further microscopical examination of several samples, I am now quite satisfied that the infilling material is sandstone, and that the official explanation is the correct one. This sandstone is very fine-grained, and is deposited in thin layers, the bedding planes being dusted over with numerous mica scales. The cavity deposits are greyish, greenish, or dull-purple in colour, and are sometimes so fine grained as to deserve the name of shales. They present in many cases a hardened, indurated appearance, no doubt due to the next sheet of lava which was poured over them. They are not all horizontally bedded as the "Explanation" says, for I noticed some inclined at a considerable angle; but this is just what we might expect from the peculiar method of their infilling. Hundreds of them can be examined along the shore, and in no case did I find any to be coarse-grained. The porphyrites, whether poured out under fresh or salt water, seem to have been deposited in deepish, still water, where the currents were not strong enough to carry along anything but very fine particles. I should not be at all surprised if organic remains should yet be found in some of these very strange deposits. Figs. 8 and 9 (Plate I.) will give some idea of their appearance in side section.

At, and below, Dunure Castle there are large stacks of rock in the sea; and to the south of this point the water comes closer up to the base of the cliffs than it does to the north. There are also

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more caverns in the rock, but into none of them do the tides appear to enter now. We observe that the inner ends of some of these old sea-caves are provided with funnels opening upwards to the grassy surface on the top of the cliffs, and at the time when the sea entered them, these would, during storms, act as immense blowers, sending forth tall jets of spray.

"See the thundering cliffs below,
How they snort and how they blow."

To the south of Dunure Castle there are many gas cavities in the rock, most of them filled with crystallised calcite, and a few with agate. About half a mile from it there is a fine display of four Raised-beaches cut out of the solid rock, but now covered with grass. They appear to occupy levels of about 10, 20, 30, and 45 feet, respectively, above the present tide-mark, and they run for perhaps a quarter of a mile, the last mentioned being 20 to 30 yards broad, and the previous one 50 to 60 yards.

At the end of the beach area described we find the Common Skullcap, a rare Ayrshire plant, growing and flowering amongst the upper gravel. The Crested Hair-grass is common all along this shore, although it is very scarce in the north of Ayrshire. We find here, too, the Greater Prickly Carex, and the Hairy-Tare, both rather scarce plants.

South of this the rock is very amygdaloidal, the gas cavities being filled with calcite, and we see some old caves about 20 feet above the present sea-level. We come to a place where the porphyrite is very dark-coloured, and the cavities nearly all filled with agates, small in size, but many very beautiful. At a point where an old sea-stack is seen standing amongst the grass, there is growing on the face of the cliff directly opposite, a large plant of ivy. As far as I could calculate it covers an area of perpendicular rock-face of about 1000 square feet, and springs from a single thick, twisted stem. The old sea-caves are the resort of many ringdoves, and as we pass along some of them get disturbed and begin their flight by that peculiar wing-clapping so characteristic of the species.

A short distance below Drumshang the porphyrites end, and below them slips what is thought to be the middle division of the Old Red Sandstone. We have thus traced these rocks along the shore for a distance of 3 miles. In this part of Ayrshire they

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cover an area of 9 square miles, extending to beyond the Doon, near Auchendrane, and rising at one point, in Brown Carrick Hill, to a height of 940 feet above tide-level. Exceedingly few dolerite dykes run through them, and on the shore only some two are seen. But this is a feature which is characteristic of igneous rocks, and perhaps shows that in cooling they do not undergo so much shrinkage as aqueous rocks do in drying.

In passing along the shore from near Drumshang to Culzean Castle we find the outline of this Old Red Sandstone district much softer, the cliffs being so much cut away that the rocks seldom reach the shore; and only here and there are the old coast-line sandstone cliffs to be seen, with grass-covered talus, and capped in places by reddish Boulder-clay. The sandstone cliffs are at first seen weathering to a yellowish colour, and the grassy slopes are traversed by those curious horizontal walks, the work of sheep. A short distance to the north of Croy little farm-steading there is a considerable outcrop of conglomerate. It is rather coarse, and of a greenish colour this hue being derived from the large quantity of Silurian mudstone pebbles it contains, some of them running up to six inches in diameter. It also contains a few greyish Silurian limestone pebbles up to 12 inches. These are of very pure carbonate of lime, some of them with a slight tinge of red crystalline calcite, and from one pebble I obtained two fossils. This conglomerate also contains pebbles of reddish syenite, red jasper, and lydian stone, some of the latter being rather angular. Interstratified with it are a few thin grey sandstone beds. One under it is a bed evidently softer than itself, as the conglomerate has been much undermined, and large blocks of it are now lying on the higher part of the beach.

For a short way the shore is sandy, and we see early potatoes are being dug from a field which is neither peat, sand, nor loam, but literally a bank of coarse gravel. The man who was working amongst them informed me that the seed potatoes are laid in open wooden trays, put in an outhouse during the winter, and allowed to sprout about 5 inches before they are planted—the small ones being selected for the purpose, and not cut, but planted whole. By this method the crop comes to maturity three weeks earlier than it would do if the seed-tubers were treated in the usual way, so that it is ready for the early market, and fetches a high price.

Before coming to Ranclcuch the sandstone cliffs are seen to have

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weathered into yellowish and reddish hues, and, at Goatsgreen, the rock is mostly obscured by trees and vegetation. On the side of the road which here ascends from the shore there is a bank of the rare Wood-Vetch, the finest of all our tares, and at the present time it is in splendid bloom, while further along we find the Enchanter's-Nightshade in flower.

Close to the shore we pass three very light-coloured dolerite dykes, and between two of these the sandstone beds are seen to be somewhat twisted. At the north end of Culzean Castle buildings, which stand on the summit of a high cliff, the porphyrites, by a fault, are again suddenly brought to view—the Old Red Sandstone cliffs having been cut about 100 yards further inland.

In the porphyrite under the Castle are several old Raised-beach caves, into which the tide does not now enter, and some parts of the rock are much cut up by natural jointings, which run through it in every direction. At the south end of the Castle grounds a wooden gangway leads on to a sea-stack, the rock of which is very amygdaloidal, and at its base a coarse agglomerate is seen dipping seawards at a angle of about 15°. The Castle itself is built of a fine-grained yellowish stone, obtained from the Old Red Sandstone formation of the neighbourhood. At the laundry the rock is very amygdaloidal, with many infillings of sandstone. We note a large oval cavity here 3 feet long by 10 inches at the widest part. It is filled with crystallised quartz, and in the quartz are a few crystals of calcite. Another cavity beside it, 3 feet by 18 inches, is filled with chert or hornstone, and calcite. In some cavities we have observed the chert is very solid, of a pale-greyish colour, and not unlike some varieties of flint.

At the little stream which comes down from the pond we find the rather rare Lesser Panicled Sedge, which in spite of its name is about four feet high, and on permanently wet parts of the sands we observe the scarce Shore Whorl-grass.

The porphyrite cliffs end at about a quarter of a mile north of the Culzean Home, and the land rises in gentle terraces, the old sea-beaches, inland from the sandy shore of Maidenhead Bay. The porphyrites are now seen in the bay as sea-rocks which are known as "the Maidens." About half tide they are rather picturesque, though not high, rising into rocky points and bosses.

Romantically situated to the west of some partially grass-covered

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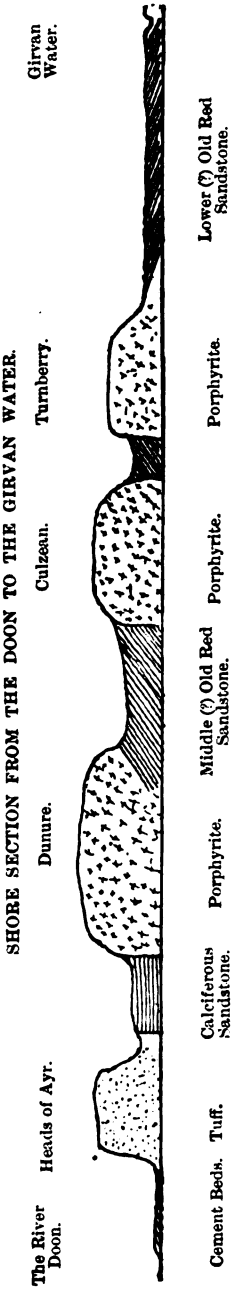
old sea-rocks are the remains of the Douglastone shipbuilding yard, a site evidently chosen more from a philanthropic than from a commercial point of view. We are again among the porphyrites, the rock being very amygdaloidal, in parts containing numerous agates. One we dig out is of a strange pattern; with minute figures of white agate of innumerable shapes, infilled with green earth, a little red jasper, and some purple patches. Between this and the old Castle of Turnberry and the Light-house the cliffs are not high, but are very much cut into by the action of the sea; we notice that the porphyrite contains the sand infillings, already more than once referred to. At a short distance from Turnberry, we note, dipping seawards under the porphyrites, a few feet of a grey ash-bed resting on sandstone.

Very little remains of Bruce's Castle at Turnberry, part of the north wall built of red sandstone being, perhaps, the most prominent feature. Onward from this the porphyrites are of a dullish-purple colour, very amygdaloidal in parts, with agate veins, and they run under the sea at about 400 yards south of the Light-house. For more than a mile the shore, which holds eastward now, is covered by bent-grown sand-hills, rising to little more than 20 feet above tide-mark. About a mile seaward from the shore we observe a long line of low rocks, stretching in a north-east and south-west direction. They are called the "Breast Rocks," and, from information supplied by two fishermen, we come to the conclusion that they must be porphyrites, and a continuation of those we last saw at Turnberry Point.

For a considerable distance there is now a good wide breadth between the shore and the old coast-line, which in parts is bounded by



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high and sloping grass-covered banks. We are now traversing the lower division of the Old Red Sandstone formation, which, for the most part, is hid by sand-drift; though at some places we note the purplish-red beds of sandstone just rising above the shingle of the beach, and quite different in colour from the sandstone rocks to the north of Culzean. In the Girvan Mains quarry, which is quite close to the shore, this rock has been to some extent worked for building-stone, but the excavations are at the present time partly filled with water.

In a ditch close by the quarry the Great Hairy Willow Herb is growing in profusion, and a few of its fine purple-red flowers are already opened, while on the bent-covered sea-margin a few plants of the Sea-Holly are to be seen, but not yet in flower. This is the land of the early potato, and from many fields the crop has been already lifted, but where it still remains we observe that the Small Nettle is about as abundant as the potato plants themselves.

At one part of the beach, beds of red sandstone and conglomerate are seen dipping towards the south-west at an angle of about 20°. From the end of the sand-hills to Girvan Water numerous boulders are met with, and the beach is at several places much covered with them. The majority seem to be granites from the Loch Doon district; they are well rounded, and many are of considerable size.

The day has all along been delightfully clear; the bold outline of Arran stands sharply out against the western sky; the southern part of Kintyre, though fainter, is not at all obscured; Ailsa Craig, "the ocean pyramid," is nearer-looking than it was in the morning; and the Ayrshire coast beyond Girvan is seen rising gradually from the sea, swelling into rounded bosses, till it culminates in hills of considerable height, which are built up of rocks very much older than those we have just traversed.

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No. II.—On the Occurrence of Pyroxene or Augite, in Large Crystals, in Two Localities in Western Scotland.

By John Young, LL.D., F.G.S.

[Read 10th November, 1892.]

The occurrence of the mineral Pyroxene or Augite, in large crystals, amongst the basic igneous rocks of this district of Western Scotland, seems to be far from common. I formerly only knew of one intrusive boss of dolerite, near Sculliongour on the Campsie Fells, which contained them. In it many of the crystals reach some half-inch in diameter, and specimens of these are now exhibited. This rock I brought under the notice of Mr. S. Allport, F.G.S., Sir Josiah Mason Science College, Birmingham, whilst he was preparing his paper on the microscopic structure and composition of the "British Carboniferous Dolerites" (*Quarterly Journal of the Geological Society*, 1874, vol. xxx., p. 529). Mr. Allport, in referring to my specimens, remarks: "A very beautiful porphyritic dolerite occurs on the south slope of the Campsie Hills, near Sculliongour. It is coarsely crystalline in texture, with large disseminated crystals of augite. The plagioclase (felspar) is well crystallised, very slightly altered, and exhibits brightly-coloured striæ in polarised light. Olivine is abundant and unusually well-preserved, some crystals being almost unaltered, others rather more so, while a few exhibit more advanced stages of its conversion into a serpentinous pseudomorph. The augite is well crystallised, and is remarkable for the number of cavities, grains of magnetite, and small felspar crystals it contains." Mr. Allport then concludes his description by stating that "the relation of this rock to the surrounding masses could not be traced, and its unusually fresh condition might lead one to suspect for it a more recent origin; but as its mineralogical composition is precisely the same as that of other rocks in the district, it has been thought better to include it here."

It is well known that augite is abundantly present in most basic rocks in the form of small crystals, or irregular grains, associated with the other minerals present. In the instance I now note it occurs in large crystals near Fairlie, on the Clyde. Some few years ago, whilst spending a day or two at this place, I wandered southwards along the shore for a mile or more in the direction of Portincross, and, it being low tide at the time, I went out on a low ridge of rock which extended seawards, and which,

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as I afterwards learned, was locally termed "The Black Rock." The outer portion of the ridge is at high water surrounded by the sea, but on the occasion of my visit I was able to get upon it, and I then noticed the large crystals of augite, but, unfortunately, having no hammer with me to break them out of the matrix, I had to be content with some fragments chipped out with a stone, and as the tide was again flowing, I had to hurry shorewards.

This year, having re-visited Fairlie for a day, and being this time provided with a hammer, I went to "The Black Rock" at low tide, and had a better examination of the composition of the rock than I made on my first visit. I found that the inner portion nearest the shore is composed of a volcanic agglomerate of dark basic rocks, cemented in a dark matrix, to which their black colour is chiefly due. The outer portion of the ridge is disconnected from its inner, or shore end, by an intermediate tract of flat, sandy beach, over which the sea flows at high tide. The crystals of augite are found in this outer rock, and they seem to be confined to a small area in its centre, which is composed of a dark, slaggy, vesicular lava, surrounded by agglomerate like that forming the shore portion. I did not see any crystals of the augite in the agglomerate, but in what seems to be the igneous rock filling the neck or orifice of this portion of the ridge the crystals are numerous and of varying size, some of them measuring three or more inches in length. The augite of which they are composed is of a dark black colour when seen in the mass, and with a shining lustre—so much so, that some of the Fairlie people who have been on the spot look on these crystals as small lumps of bright cherry coal embedded in the rock. They are now very rough, much fissured, and irregular in form and outline, as many augite crystals are, owing to weathering; but their weight, and the density of the rock in which they have segregated, clearly indicate that they belong to the later erupted group of basic igneous rocks and minerals.

Augite is one of the pyroxenic group of minerals, of which there are several distinct varieties said to be due to isomorphous changes in the pyroxene, whereby it has taken up other mineral elements. Pyroxene is the name now employed for the whole group, and augite the name for the black varieties. The latter is composed chiefly of silica, magnesia, lime, and iron, and where it occurs in the more basic igneous rocks, the iron is some-

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times present to the extent of from 10 to 20 per cent. Professor Dana mentions, in his "Text-Book of Mineralogy," that the name "pyroxene" was originally given to the mineral by Hauy, the name implying that it was a stranger to the domain of fire; "whereas," says Dana, "it is in fact, next to the basic felspars, the most universal constituent of the igneous rocks." He also states that the name of pyroxene, in spite of its error, has been retained in preference to others, because Hauy was the first to point out its distinctions from hornblende, and all the others of the amphibole group of minerals with which pyroxene was so often confounded by the earlier mineralogists.

Crystals of pyroxene in several varieties have been developed in many of the older metamorphosed sedimentary rocks in which the elements of the mineral were present; but the variety augite —its heaviest and most basic form—is the one which seems to be always associated with rocks of volcanic origin. It will be seen, by a comparison of the Campsie augite with that from "The Black Rock," that the matrixes of the two are very dissimilar—the former showing a well-crystallised structure, as I have already stated in the quotation from Mr. Allport's paper, while the specimens from "The Black Rock" show no apparent crystallisation beyond that seen in the augite crystals themselves. But a lens shows the matrix to be full of minute cavities, in which no other mineral is present, the rock being as porous and vesicular as many of the recent lavas. In a section I prepared for the microscope, this open, porous structure is well seen, as also that the crystals of augite are little altered. I therefore think that both the erupted boss at Campsie and that forming "The Black Rock," near Fairlie, belong to eruptions much later than those of Carboniferous times. Sir A. Geikie, in his Address to the Geological Society, 1892, "On the Volcanic Rocks of Britain," points out numerous vents, more recent than Permian times, in Ayrshire and other tracts of central Scotland, and "The Black Rock" may be one of these. In the lava now filling this old vent pyroxene in the form of augite seems to have been the most abundant mineral constituent, segregating into small, rough, crystalline masses from the still molten lava, ere the rock itself had solidified, or had developed any further crystalline structure.

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No. III.—On the Origin of Certain Granite Boulders in the Clyde Valley. By Dugald Bell, F.G.S. With a Sketch Map.

[Read 8th December, 1892.]

More than fifty years ago, the late Mr. Smith of Jordanhill—one of the founders of Glacial Geology—noted the occurrence of a certain number of granite boulders in the "Till" around Glasgow, and estimated their proportion as about 1 per cent. of the whole stony contents. About 60 per cent., he observed, were of sandstone and shale derived from the subjacent Carboniferous rocks; 30 per cent. were of trap from the Kilpatrick hills, about ten miles to the north-west; 9 or 10 per cent. of clay-slate and "greywacke" from mountains in Dumbarton and Argyle shires, about twenty miles away in the same direction; while "the granite blocks must have been transported from still greater distances. Beyond the Kilpatrick hills," he added, "the trap and white sandstone boulders disappear and are replaced by greywacke, clay-slate, and red sandstone, while those of granite and mica-slate become numerous," and also increase in size. The inference was, therefore, in all respects well supported that "the cause which produced the diluvial covering of the great coal-field of Scotland must have had its origin to the westward."*

As to the exact locality from which these granite boulders had been brought, Mr. Smith at first thought of Inveraray for some, and even of Ardnamurchan for others; but ultimately seemed to prefer Ben Cruachan as the most likely source. Thus, finding a small granite boulder in the "Till" at Chapelhall, near Airdrie, he remarked that to the east and south of Glasgow such boulders are comparatively rare and small, "but as we go to the north-west they increase both in number and in size. The nearest granite rock in that direction is at Cruachan about sixty miles to the north-west of Airdrie."†

The obvious difficulties regarding their transport from any of the localities named (by "violent floods," as was then supposed, or by any other agency that could be suggested) led Mr. Smith for a

* "On the Last Changes in the Relative Levels of Land and Sea." read to the Wernerian Society, 1838; republished in "Researches in Newer Pliocene and Post-tertiary Geology," 1862. Pp. 12, 13.

† "On the Occurrence of Marine Shells, &c.," read 1850, *Ib.*, p 141.

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time to suppose that the "Till" might be as ancient as the elevation of the intervening mountain ranges (!) and "was most probably caused by the violent geological action by which it was accompanied."‡ Such conjectures belong to the infancy of every science.

From that day to this, though the supposed agency of transport has been changed, the locality from which these Clyde granites have come has been generally believed to be the same, viz., Ben Cruachan. It was the best known granitic area within what seemed to be a reasonable distance in the direction required, the rock near Inveraray not being a true granite, but a quartz-porphyry; while if it be "a far cry to Loch Awe," it is a much farther one to Ardnamurchan or the Ross of Mull. Accordingly, at the various excursions of the Glasgow geologists and naturalists, whenever the members came upon a granite boulder, they were usually content to note it as "probably from Bunawe or Ben Cruachan."

Gradually, however, doubts have intruded. The majority of these boulders are of a grey, rough-grained granite, with large flesh-coloured crystals of felspar, easily recognisable, and differing distinctly from any granite known to belong to the Bunawe or Ben Cruachan district. Besides this, it became increasingly difficult to see how, by any conceivable means, the boulders in question could be transported from that quarter.

At this time of day we may dismiss "floods" and also "icebergs" and restrict ourselves to land-ice, as the only probable or possible agency of transport. But the difficulty which Mr. Smith pointed out, that "the intervening space is intersected by deep arms of the sea and steep precipitous mountain ranges," and which is fatal to the first two of these agencies, applies with sufficient force also to the third.

For, when the country was enveloped in land-ice, with great sheets or streams of it descending by all the principal valleys to the sea—such being the admitted conditions—the ice from Ben Cruachan and the surrounding granite district would evidently find its way seaward, partly by the Loch Etive branch of the great ice-sheet on the one hand and partly by that of Loch Awe on the other. There is every proof that Loch Etive was filled from side to side by an immense glacier, originating in the mountainous region at the head of it, which carried all boulders

‡ *Op. cit.*, p. 13.

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on that side out westward towards Oban and the Sound of Lorne. Bunawe is therefore out of the question. On the other, or eastern, side of Ben Cruachan, there is equally clear evidence that Glen Strae, Glen Orchy, and Glen Lochy, were each filled with ice from the same region, which, coalescing, filled the channel of Loch Awe, and moved south-westwards by Ford and Kilmartin, out to the Sound of Jura. Similarly it can be proved that the channel of Loch Fyne was occupied by a great mass of ice from the eastern part of the same region, moving south-west in such volume, that at Ardrishaig, instead of conforming to the bend of the loch there, it went, in great part at least, straight across the isthmus of Knapdale, and so out to sea.* It is impossible, therefore, to imagine boulders first crossing the south-westward moving body of ice in Loch Awe, and finding their way eastward into Loch Fyne, then crossing the south-westward moving body of ice there, and still finding their way eastward into this part of the Clyde valley.

Judging from the marks of glaciation over the district generally, it has long appeared to me that the parent locality of the boulders in question was most probably somewhere in that mountainous tract which lies between the head of Loch Fyne on the one hand, and of Loch Lomond on the other. Many years ago the late Professor James Nicol of Aberdeen, in his Geological Map of Scotland (1858), indicated two small areas of granite in that district; and the fact that so careful an observer had done so lingered in memory as supplying the most likely solution of the problem. One or two visits to the locality, however, failed, from not traversing it sufficiently, to verify Nicol's indications. Meantime, Murchison & Geikie's "First Sketch of a Geological Map of Scotland" (1861), and Geikie's own larger Map (1876), contained no sign of granite in that locality; so that the origin of the boulders appeared to be still to seek.

Some years ago, being at St. Catherine's on Loch Fyne, opposite Inveraray, I was struck by the immense number of granite boulders strewn about the hillside and along the shore, quite resembling those of whose origin we are in search. These boulders, it was apparent, could not have come across the loch, there being no such rock *in situ* there; while the entire drift and movement of the ice in the locality had evidently been southward. Clearly, there must be an area of granite northward, somewhere about the head

*T. F. Jamieson. *Quart. Jour. Geol. Soc.*, vol. xviii.

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of the loch or beyond it, probably in that little-known region already indicated, extending between the upper part of Glen Fyne and Glen Falloch. In that conclusion I rested till circumstances should enable me more fully to explore the locality, or should furnish some additional confirmation, or some distinct proof of the accuracy of this inference.

That confirmation or proof has now been furnished. The officers of the Geological Survey have lately described a remarkable "area of plutonic rock" on the eastern side of upper Glen Fyne, extending from that glen over to, and in one part somewhat beyond, the watershed between it and Glen Falloch. This plutonic area is about twelve or thirteen square miles in extent, of which ten are occupied by granite, chiefly by a "porphyritic granite," so named from the presence of "large crystals of orthoclase, measuring often two inches across." A stripe, however, on the eastern side is occupied by "granite not porphyritic," by tonalite (or quartz-diorite), and lastly, adjoining the mica-schist, there is a broken belt of diorite. These particulars are taken from a valuable paper by Messrs. Dakyn and Teall of the Survey, published in the *Quarterly Journal of the Geological Society* for May, 1892. The paper does not refer at all to the *dispersion* of boulders, its sole object being to exhibit the chemical and mineralogical proofs that we have in this area, the results of the "consolidation of a vast subterranean reservoir of molten rock.*

I have since spent a long summer day amid the solitudes of this mountainous region, where I found the granite *in situ*, and have no doubt of its being the true origin of the boulders referred to. I need hardly point out how entirely it accords with all the known facts of their distribution, and of the glaciation of the district. By Loch Fyne, Loch Eck, and the Holy Loch, a large number reached the opening of the Firth of Clyde, and some were carried right across the Channel to the neighbourhood of Gourock. By Loch Sloy and Loch Long many also found their way into the Gareloch, and along the northern shore of the Clyde near Helensburgh and Ardmore, and on towards Cardross and Dumbarton. Some were also carried from Garelochhead over into Glen Fruin, in the upper part of which they are numerous, becoming fewer down towards the school house, near which, however, there are two or three, and at

* "On the Plutonic Rocks of Garabal Hill and Meall Breac," *Quart. Jour. Geol. Soc.*, vol. xlviii., p. 104.

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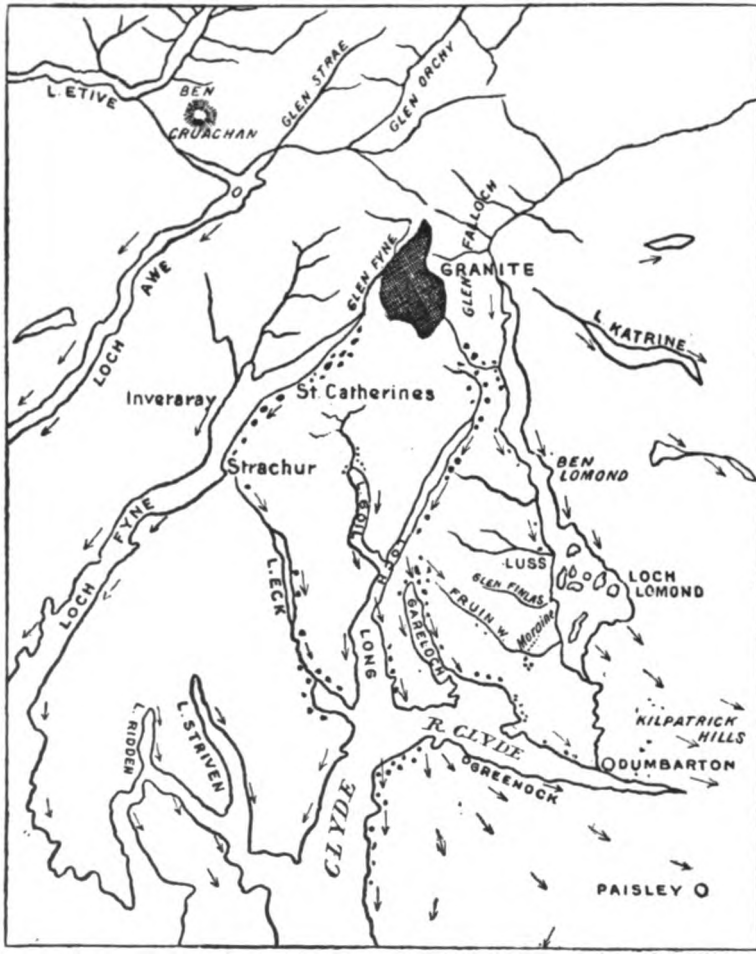
least two reached the "moraine." A more limited number from the eastern side of the watershed appear to have passed into the Loch-lomond valley, scarcely, if at all, by Glen Falloch, but chiefly by some of the side-glens further south, as at Upper Inveruglas, Tarbet, &c., and ultimately contributed their quota to those strewn on the flanks of the Kilpatrick hills, or imbedded in the



Sketch Map showing distribution of the Granite Boulders.

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"Till" around Glasgow (see Sketch Map, p. 20). Further details will be found in the following "Appendix." But it may here be added that boulders of the other rocks in the "plutonic area" described—the finer granite, diorite, &c.—are frequently found associated with the porphyritic granite, and so furnish additional confirmation of the conclusion now stated.

Since reading this paper I have learned, from a reference kindly furnished by Mr. Jamieson of Ellon, that the late Mr. Hopkins, of the Royal Society and the Geological Society of London, indicated the same locality as has now been specified for the origin of these granite boulders. In a paper read to the Geological Society in 1851,* Mr. Hopkins states that his attention was directed to the matter by his friend Mr. Smith of Jordanhill, and that "the source of those blocks presented a great apparent difficulty." Ben Cruachan was the nearest known source to which they could be referred; but "at the same time the nature of the country intervening is such as presented the greatest difficulty in any explanation of the dispersion of these blocks which should refer their origin to that mountain."

Mr. Hopkins goes on to narrate that, accompanied by Mr. Montgomery of Ayr, he devoted several weeks of the summer of 1850 to a more detailed investigation of the subject. The conclusions he was led to form were, that certain blocks of dark-grey granite were derived from Ben Nime [Ben Ime], a mountain near Loch Sloy, to the north of Loch Long; but that those of light-grey granite, "with large crystals of felspar," which are very numerous about the head of Loch Fyne, "proceeded from a great mass of granite about 4 or 5 miles north of the loch," and extending eastward to the north of Loch Sloy. This is evidently the tract now more particularly described by Messrs. Dakyns & Teall; and it was doubtless from Mr. Hopkins's paper that Prof. Nicol inserted the two little areas of granite in that quarter in his Map of 1858.

It is perhaps remarkable that Mr. Smith in publishing his well-known little volume of "Researches," eleven years afterwards,

* *Quart. Jour. Geol. Soc.*, vol. viii., p. 20.

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took no notice of Mr. Hopkins's observations, though they were due to his own suggestion, and removed what he had felt to be a difficulty. The explanation probably is, that Mr. Smith, being then an old man, allowed his papers to be reprinted very much in their original form, and except a few casual notes, made no attempt to bring them up to date. Thus, Mr. Hopkins's observations seem to have been largely overlooked even by professional geologists, as the Maps we have mentioned show, till now happily recalled in connection with this paper.*

* I may add that Mr. Hopkins also gave a Sketch Map of the district, showing the distribution of the boulders, which I had not seen when drawing up my own. The following are the principal points of difference between them :—

1. On *Loch Fyne*, Mr. Hopkins showed boulders to opposite Inveraray, but no further ; none at Loch Goil, Strachur, Loch Eck, or the Holy Loch.

2. On *Loch Long*, only at Arrochar, and thence across to Lochlomond ; none at Garelochhead, but the line resumed at the foot of the Gareloch and at Kilcreggan, and continued uninterruptedly up the Clyde to near Renfrew.

3. On *Lochlomond*, a continuous line from the head to the foot of the loch (west side) and down the Vale of Leven, joining the Clyde line at Dumbarton.

4. None marked on the opposite shore, near Gourock.

[The greater part of this paper was also read to the Glacialists' Association in August, and appeared in the *Glacialists' Magazine* for September, 1893. Specimens of the granite from the various localities named were also exhibited at the meeting of the British Association for the same year.]

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NOTES ON THE LOCAL DISTRIBUTION OF THE GRANITE BOULDERS.

(1) LOCH FYNE GROUP.—Towards the head of the loch, at St. Catherines, and downwards to Strachur—very numerous and often large.

Loch Long.—About 10 or 12 near the head of the loch.

Loch Eck.—Several, not large, along the eastern shore of the loch and on the hillside.

Holy Loch.—Around the head of the loch and along to Hunter's Quay—a good many. Beyond Kilmun on the one side and Hunter's Quay on the other—none observed.

(2) LOCH LONG GROUP.—Near Arrochar and up towards Loch Sloy—very numerous and often large. At the Arrochar end of the cross valley to Tarbet, and for some distance along it—several; fewer towards Tarbet.

Cove to Kilcreggan.—Fairly numerous, 12 to 15 observed (none seen on the western side opposite, near Blairmore).

Gareloch.—About Garelochhead and on towards Shandon—very numerous (only a few seen on the west side of the loch, near the head).*

Glen Fruin.—Part of the same series as Garelochhead. Numerous in the upper part of the glen, diminishing towards the lower part. One of good size, however, on a knoll more than half way down; a few near the school; and at least two on the "moraine."

Helensburgh and Ardmore.—A few at the west end: one of fair size on the shore near Ferniegair, and three or four at the east end near Craigendoran. At the projecting point of Ardmore, they again become numerous, over 40, large and small, having been counted within half a mile. A few found higher up, also, on the western side of Benbui.

Cardross to Dumbarton.—A few; sufficient to mark the continuity of the line.

(3) OPPOSITE SIDE OF THE CHANNEL.

Gourock to Inverkip.—From Kempoch Point to Cloch Lighthouse—about 20, mostly of moderate size. From the Cloch to Lunderston Bay, about 10, some large.

* Many of these boulders have been built into dykes and the sea-wall.

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Fairlie to beyond Hunterston.—10 or 12, some of good size (not Arran granite, as some have curiously imagined, but distinctly north-east Argyleshire).

Cumbrae.—A good many at the north end, and 2 of good size at Millport.

(4) LOCHLOMONDSIDE.

Glen Falloch.—Few, if any. Mr. Hopkins records he found *none* in the glen. From the position of the granitic area, it is evident that Loch Fyne and Loch Long would be the principal channels of dispersal. Further down, however, they appear, but not very numerously, as if brought in by some of the side-glens from the west.

Below North Inveruglas, and near Tarbet and Luss, some are found; then very few, if any, along the lower part of the loch, on its western side; and none have been observed in the upper part of the Vale of Leven.

Near the foot of the Vale of Leven, however, they appear on the hillside near Overtoun, and behind Dumbuck, near Bowling, apparently where the Loch Long or Gareloch ice, in its eastward progress, would impinge on the hills there. A few were also found in the recent railway excavations near Bowling, and some near Bishopton on the opposite side of the river; and so on into the Glasgow district, where no considerable excavation can be made without discovering some of them. (At Partick, Jordanhill, Garscube Road, and Hamilton Hill a good many have been unearthed.)

Eastern Side of Lochlomond.—In its lower part 2 or 3 have been observed. And in the Strathendrick Valley, near Killearn and Balfron, several have been found, clearly proving that the Lochlomond ice had the same easterly trend which the distribution of the boulders along all the lochs mentioned shows was the prevailing, or general, direction over all this adjacent part of the Clyde Valley.

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No. IV.—On a Section of Carboniferous Strata near Giffen Station, Ayrshire. By John Smith. With Two Sections.

[Read 12th January, 1893.]

In the first cutting of the Kilbirnie branch of the Caledonian railway, a short distance from Giffen station, a small section of Carboniferous rocks is exposed, their position being in connection with the horizon of the Highfield limestone.

This section would perhaps not be worthy of special notice but for the occurrence in it of a bed of sandstone which, from its close proximity to a fault, has become bent in a remarkable manner. The total length of the section is about 320 feet, and the strata are seen in this short distance to occupy a syncline, an anticline, and half an anticline, the latter feature being brought about by a fault. Two faults are also to be seen, though there are probably three, one being hid by the pier of the railway bridge.

Commencing at the east end of the section, we first see a bed of sandy shale, slightly micaceous, with non-septarian ironstone nodules, a few being of the slickensided variety. This bed dips 10° towards the west. Above it there are 2 feet 6 inches of fireclay, slightly micaceous, and containing rootlets, and where the mica is abundant the fireclay is of a harder texture than it is elsewhere. Over this is 1 foot 4 inches of coal, which is a mixture of splint and free coal, and the jointings are either filled with carbonate of lime or bisulphide of iron. Above the coal is 1 foot 4 inches of black shale; and above the shale lies 2 feet of light-coloured shale, penetrated by thin dykes of sandstone.

These dykes, which are unusual and curious, are connected with the clayey sandstone bed above. As they are infillings, and are composed of the same material as the latter bed, the explanation seems to be that the sand has run into cracks to the depth of 3 feet in the clay which formed the shale. The cause of these cracks is not apparent, as only their edges are visible, but it is very likely that they are just deep sun-cracks. The clayey sandstone, 6 feet thick, at first dips with the bed above described, but ultimately runs level till it comes to a fault. Its bottom part is pure for 11 inches, but all the rest contains innumerable particles of carbonate of iron about the size of pin heads, which are well seen after the sandstone has slightly weathered.

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On the west side of the fault already mentioned 6 feet of, apparently, the same sandstone are seen, with 3 feet of shale and 1 foot of sandstone above that. These three beds lie horizontal as far as the bridge. On both sides of the fault the clayey sandstone has its jointings, to the breadth of 5 feet, coated over with a substance of a bright bluish-green colour.

On the west side of the bridge the strata dip towards the east at an angle of 57°, which, combined with the different beds met with, shows that there is a break somewhere about the spot where the bridge is built.

The first strata seen on the west side of the bridge are 16 feet of shale, with sandstone plies, small non-septarian ironstone nodules, and very minute particles of mica. Below this occur 8 feet 9 inches of sandstone plies which have become iron-stained by exposure to the weather. A few inches at the bottom of this bed, not so iron-stained as the rest, shews cross-bedding of a very small and unusual pattern (fig. 1). Below the sandstone there are

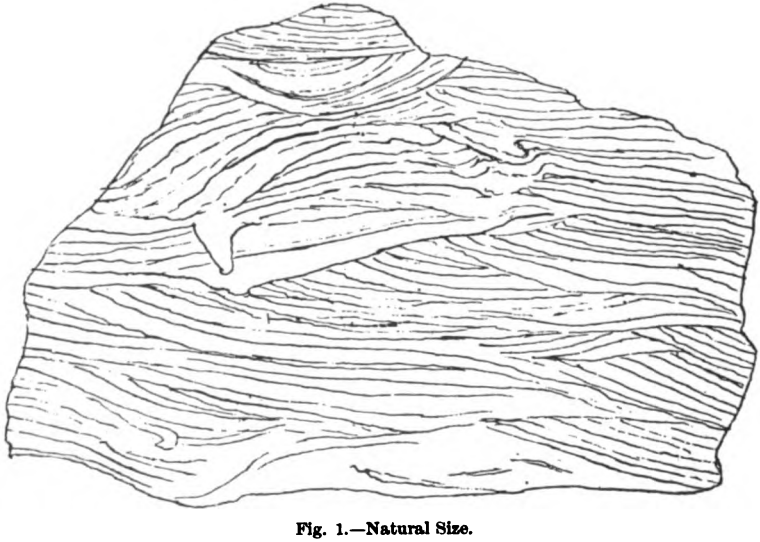

Fig. 1.—Natural Size.

9 feet of non-septarian ironstone nodules, and fragmentary Carboniferous fossils in the bottom part. The east part of this bed dips with the strata last described, but runs level towards the west till it comes to a fault, the "vees" of which is filled with

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splintery black shale. On the east side of the fault *b*, the Highfield (calmy) limestone *c*, 5 feet 8 inches thick, dips steeply towards the east. Weathering has given it a yellowish colour, and it contains traces of *Streptorhynchus*, *Productus*, *Nautilus*, and other Carboniferous fossils. On the west side of the limestone is a fault, the "vees" of which is filled with splintery and crumbled black shale, and a large limestone nodule with *Productus latissimus*. On the west side of this fault is the remarkable curve in the sandstone bed which gives the section its peculiar interest. This bed is 6 feet thick, and is made up of five principal plies *a*, fig. 2. Dipping at first steeply towards the east, it immediately bends round and dips towards the west, the bend forming a curve of which the sharpest radius is 5 feet 10 inches. Although this bed curves so sharply, it shews no gaping openings towards the top, and no more joints than many an ordinary bed of sandstone.

I believe it is an accepted canon in geology that faults and bendings in the strata have been produced in a very gradual manner, and I think the sharp curving of this bed of sandstone is additional proof of the general truth of this law. Had the bending taken place suddenly, the sandstone would certainly have shewn gaping cracks towards its upper surface, but having been brought about slowly, and probably by movements at long intervals, its component particles had time, during the intervals of motion, to accommodate themselves to the strain put upon them, so that ultimately the bed assumed the sharply curved form in which we now find it. This curved part of the sandstone is considerably harder than the rest of the bed, and one of the plies looks as if it had been crushed, although where the bed is not bent this ply has the same crushed appearance. About two years ago, in the Ashawburn quarry at Muirkirk, I saw some of the limestone beds bent into quite as sharp curves as that of this sandstone bed, which is so conspicuous that it is popularly called in the district "The Wheel" (see fig. 2, page 28).

Above the sandstone there is to be seen a bed of 3 feet of black shale, dipping at about 40° to the west, and having dispersed through it very minute mica scales. Over this bed lie 8 feet 8 inches of sandy plies, slightly micaceous and shaley at the bottom. Then beneath come white shale, 1 foot 6 inches; sandstone, 1 foot; yellow argillaceous sandstone, 4 feet 6 inches, with rootlets in the upper part; and free coal, 10 inches.

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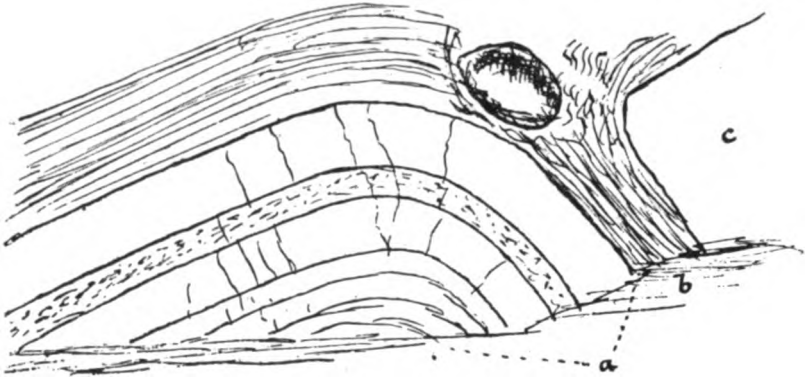

Fig. 2.

(*a*) The Bent Sandstone beds.
(*b*) Fault.
(*c*) Highfield Limestone.

It is sometimes argued that, because coal-beds rest on sandstones or are overlaid by limestones, they must have been formed from drifted material. In the *Geological Magazine* for April, 1892, there is an article on this subject, but the details of the sections given are not minute enough to allow a reader to form a definite opinion. Here, in the Giffen cutting, is a coal-bed which rests on sandstone, and is overlaid by a thickish limestone, and yet I think there can be no doubt, from the rootlets in the sandstone, that the vegetation which formed the coal grew on the spot where it now is, and also because this thin coal-bed covers a very wide area. Above the coal are 5 inches of shale, and 5 feet 9 inches of limestone, the same post we have already seen at the last two faults. Above the limestone are 1 foot 4 inches of shale and 9 inches of calmy limestone, and these complete the section.

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pl. X., Plate II.

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No. V.—The Geological Position of the Irvine Whale Bed. By John Smith. With an Illustration [Plate II.].

[Read 9th February, 1893.]

Skirting the coast of Ayrshire are certain loose deposits of sand and gravel, at some places represented by beds of clay, which are found up to at least 120 feet above sea-level. These are especially well marked in the district between Ardrossan and the Doon, and nowhere better than about Irvine and Kilwinning, where they reach their greatest breadth, stretching about four miles inland from the present coast-line. Some of the best exposures of these beds are to be seen in the lower reaches of the Irvine Water, for a mile below, and two miles above, Irvine Town Bridge.

Near the artillery battery, on the north side of the Irvine Water, and a short distance below the Glasgow and South-Western Railway bridge, the following section is to be seen:—

	Feet.	Inches.
1. Sand with Gravel and Current-bedding,	24	0
2. Black Mud,	1	5
3. Reddish Sandy Mud,	0	7
4. Black Mud,	0	10
5. Reddish Sand,	1	6
6. Reddish Gravel,	1	0
	29	4

In this section high tides rise to about bed No. 4. In the 3rd and 4th beds are specimens of *Ostrea edulis*, *Cardium edule*, *Littorina littorea*, *Mytilus edulis*, *Pecten maximus*, and *Scrobicularia piperata*, some in good condition; the bivalves often have the hinge ligament attached, though much decayed, but the smaller shells, though often retaining their shape, are all in a soft, pulpy state. In the thick, upper sand-bed no shells are to be seen, having evidently all been dissolved away by the action of carbonated water.

At Kidsneuk, on the north-east side of the river, the recently-constructed Irvine branch of the Caledonian Railway made a long section through part of these beds, and it was interesting to observe how the different layers all dipped regularly at a gentle angle to the north-west. So much was this the case that had the section been one of solid sandstone, instead of loose sand and gravel, with merely a deposition-dip, one would have been very apt to say that here we had a series of sandstones, several hundred feet thick,

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originally deposited horizontally, and afterwards tilted. No doubt the different beds cannot all be of the same age; the layers towards the south-east must of necessity be older than those towards the north-west, and yet sections cut in them at different parts would appear to pass through the same sand-beds. In this section, at about five feet from the surface, and, resting on the outcropping edges of the sand as if it had been unconformable to it, there was a bed of peat of the consistency of liver, five inches thick, and with numerous fine sand-grains dispersed through it. The sand-bed above this peat was of a yellowish colour, the result of oxidization of the iron-bearing materials in it. The sand below it was greyish so far as it was cut into—13 feet—having been prevented from being oxidised by the water-tight peat-bed. Towards the north end of the section there were six feet of black mud interstratified with the sand; and at some points the sand-beds were highly iron-stained, the staining often running *across* the bedding.

In a sinking for a pit not far from the railway cutting near Ravenscroft, the following section was passed through:—

	Feet.	Inches.
1. Fine Reddish-yellow Sand,	5	0
2. Peat,	2	0
3 Fine Grey Clay,	0	2
4. Grey Sand, with Pebbles,	1	11
5. Peat,	1	1
6. Sand and Gravel, with Sea-shells,	2	0
7. Sand and Large Gravel, with Sea-shells,	3	4
8. Gravel, with Sea-shells,	2	0
9. Boulders mixed with Sand and Clay, with Sea-shells,	2	0
10. Boulder-clay, very tough (ground moraine),	12	0

The peat-beds (Nos. 2 and 5) contained remains of beetles, with the metallic lustre on the wing-cases beautifully preserved, also cocoons, and seeds of plants. The lower one contained 5·35 per cent. of ash, which is just about the same quantity as is found in some Carboniferous coals, although, were this peat converted into coal, the proportion would be greater. In beds 4 and 6 a number of tree-roots lay in the position in which they grew, oak and birch being conspicuous: some parts of the oak were very black and exceedingly hard and solid. The beds between the lower peat and the top of the Boulder-clay contained a number of sea-shells in good

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preservation, but none of an arctic character. No. 9 bed shows a characteristic feature of this formation where it rests on Boulder-clay, the boulders in it having been washed out of the Boulder-clay by marine denudation before the sand and clay were deposited amongst them. When the Caledonian Railway was being made between Saltcoats and Ardrossan, a peat-bed, similar to those above described, was exposed in a long section in the Raised-beach formation.

On the east bank of the Irvine Water, opposite Williamfield, the following section may be seen :—

	Feet.	Inches.
1. Blown Sand,	6	0
2. Old Sandy Soil,	1	2
3. Hard, Rusty, Dark, Wavy Band,	0	0½
4. Sand, with Patches of Gravel and Sea-shells,	21	0
5. Compact Rusty Gravel,	1	2
6. Hard, Tough, Compact Peat,	0	8
7. Tough Grey Clay, with Plant-roots,	0	3
8. Yellowish White Sand, with Plant-roots,	0	10
9. Rusty Iron-bound Gravel,	4	8
	35	9½

The thin layer or "wavy band" (No. 3) is characteristic, and has resulted from the washing out from the sand of iron oxide which has been re-deposited. It is called "hard-pan," and I have seen it an inch or two in thickness, and sparkling like spathic iron ore. Much of bed No. 4 is current-bedded, and some of the finer beds contain numerous burrows filled with light-coloured sand. These burrows, which run up to ⅞-inch in diameter, are of many varieties of shape, and ramify in every direction, especially in a horizontal one. They have evidently been formed by marine annelids, burrowing amphipods, and probably some other animals. Beds 5 and 9 are remarkable from the fact that they are harder than many a more ancient conglomerate. Bed No. 7 is composed of the toughest peat I have ever seen. It is made up to a large extent of what appear to be the leaves of *iris* or *sparganium*, with a few branches of forest trees; and in it I have detected a very few remains of beetles and of hazel-nuts. When dried and broken across the bedding it shows traces of glistening, coal-like fracture. It is regularly jointed, with "backs and cracks" in the manner of an ordinary coal, and contains iron pyrites, both in the joints and in

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the solid parts, which shows that these features, at least in some cases, are early developed in the history of a coal-seam. The pyrites occurs both as thin plates and as small granular lenticular masses, and is as bright and sparkling as when found in a coal-bed. In this bed it often covers the surface of the vegetation as thin sheets. In the thick sand-bed above the peat I have found marine shells, and this fact, combined with the burrowings already noticed (and which we shall again notice in beds with abundance of marine shells), proves that *the peat-bed has been submerged by the sea.* That the peat was formed in a marshy bit of ground *above sea-level* is shown by the fact that the clay-bed No. 7, below it, together with No. 8, is penetrated by plant-roots. Under the peat-bed I found a small, black chalk-flint. The tide at present rises to about the bottom of bed No. 9.

The section exposed in the cutting for the Ravenscroft Bridge foundation was as follows :—

	Feet.	Inches.
1. Yellowish Sand,	3	0
2. Peat,	0	11
3. Greyish Sand,	6	0
4. Peat, with Tree-roots,	1	0
5. Bluish Sand, not cut through,	—	—

In Eglinton policies, about half a mile from this, there is a thin mud-bed, *on the top of the upper peat*, with *Littorina littorea* and *Ostrea edulis*, showing that this peat also was submerged beneath the waves. In Bartonholm sand-pit the following was the section in 1881 :—

	Feet.	Inches.
1. Sandy Soil,	1	6
2. Sand, with Thin Layers of Gravel and Current-bedding,	9	0
3. Sand, with Worm- and other Burrowings,	3	0
4. Sand, with Layers of Small Pebbles,	3	0
5. Sand, with Worm- and other Burrowings,	5	0
6. Dark Mud, with Oyster-shells and Patches of Drifted Peat, forming the bottom of the pit,	—	—

The burrowings in beds 3 and 5 were filled with sand very much lighter in colour than that of which the beds were built up. Many of them were almost circular in cross section, and from $\frac{3}{8}$ to $\frac{7}{8}$ inch in diameter. They extended mostly in a horizontal direction, but twisted about and up and down considerably. When passing

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through sand tinged with hydrated iron oxide they were of a slightly fulvous hue, but one side of the track was often of a deeper colour than the other, which showed, I think, that the colouring matter was added subsequently. In fact, this was well seen in some parts of the section where broad bands of varying fulvous shades passed in an oblique direction through the strata. In this section were numerous stones up to 4 inches in diameter, and large pieces of water-worn gas-coal, derived from the outcrop of the "parrot" coal-seam. When pieces of wood were got they were invariably crusted over with hydrated iron oxide.

At 10 feet from the top of this sandpit I picked out of the stratified sand a hollow-chipped chert implement.

In the cutting made for the Caledonian Railway through Byrehill Farm, near Kilwinning, the following section of the Raised-beach beds was exposed towards its south-western end :—

	Feet.	Inches.
1. Sandy soil,	1	0
2. Yellowish Sand,	7	0
3. Sandy Mud, dark coloured,	2	8
4. Peaty Sand and Water-worn Sticks,	0	2
5. Dark Sandy Mud, with Sea-shells,	1	4
6. Solid Brown Peat,	0	2
7. Yellowish Sand and Gravel,	2	6
	14	10

Four beds, Nos. 3, 4, 5, and 6, contained water-worn pieces of wood. In bed No. 5 were numerous specimens of *Ostrea edulis* and *Littorina littorea*. A short distance to the west of this section, in a sinking made for the railway bridge over the little Penny Burn, numerous recent marine shells were found in grey sand, the level of which was lower than that of the beds in the above section. In part of the same sinking several morticed oak beams of a crannog were discovered. In a section at Stevenston sandstone quarry a bed about two feet thick, almost completely made up of *Littorina littorea*, rests on light-coloured shale of Carboniferous age, the top of the shale being riddled with the holes of *Pholas*, although the *Pholas* shells themselves have been dissolved away. This shell-bed is a little below sea-level, and is covered by a few feet of gravelly sand which rise slightly above it. These probably represent a time when the land was rising just after the Raised-beach period.

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In the Heatherhouse pit, near the Irvine Chemical Works, the following section was passed through :—

	Feet.	Inches.
1. Sand, yellowish in upper part,	15	0
2. Peat,	2	6
3. Grey sand, with numerous Sea-shells,	18	6
4. Boulder-clay,	21	0
5. Sand and Gravel,	3	0
6. Boulder-clay,	18	0
	78	0

No shells were found above the peat-bed, No. 2. They first showed a little below it, at a distance of 20 feet from the surface ; and I collected in all 42 species of mollusca, none of them of a boreal character, but all true Raised-beach types. No shells or other organisms were got in the sand-and-gravel-bed between the two beds of Boulder-clay. A large quantity of water flowed from this bed, which showed that it was either of considerable extent, or that it cropped out below the upper Boulder-clay against the sand above. Some of the Boulder-clay was laminated, and contained well-striated stones.

On the side of the Irvine Water, between Warrix and Shewalton Mill, is the following section :—

	Feet.	Inches.
Sand, stony at bottom,	8	0
Boulder-clay (so far as seen),	7	0

A peculiarity of this section is that the Boulder-clay is cut up by numerous vertical jointings about 3 inches apart. On top of the clay are a number of sea-shells, all more or less decomposed.

By far the finest of all the Irvine Water sections, and notable as the one in which Whale remains have been found, is at the great bend in the river at Shewalton Moor, a mile above Irvine Town Bridge. The section exposed here on the south and west side of the river is about 400 yards in length, and as it is undergoing rapid denudation, every flood in the river exposing a fresh face, it is at all times open to examination. This section, besides containing a large number of marine remains, has at various times yielded bones of the Whale ; and from the Heatherhouse pit, sunk through the same beds a short distance to the west, was got a molar tooth, which Mr. Newton of the English Geological Survey informs me is that of a horse. The Rev. David Landsborough,

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from information received from a former Provost of Irvine, says, in the *Kilmarnock Standard* for November, 1892, that Whale remains were found at the above locality by Mr. Andrew Currie, rope-spinner, Irvine, in 1790; and it was no uncommon thing at one time for the Irvine weavers to have Whales' vertebræ attached to their frames as loom-weights.

In 1863 part of a Whale's skull was found at the head of the "great bend" by Mr. Hugh Jack, of Oldhall. It created a considerable sensation at the time, and I remember going with a number of other lads to see it. It is now in safe keeping in the Hunterian Museum, Glasgow. On the 11th November, 1892, Mr. Joseph Downs, carpenter, Irvine, found, near the middle of the "great bend," and 250 paces from where the specimen was got in 1863, a portion of another Whale's skull. He immediately wrote to me on the subject, and we went together to see the specimen *in situ*. It was lying in darkish sand, about 3 feet above the level of the water in the river, and perhaps 10 feet above high-tide-level. This specimen is now in the Edinburgh College Museum, but Sir William Turner has not yet been able to say to what species of Whale it belongs.

The section of strata at the "great bend" is as follows:—

	Feet.	Inches.
1. Turf, with Heather,	1	0
2. Yellowish Sand, without Shells (with stones up to within 4 feet of the turf),	8	0
3. Grey Sand, with numerous Sea-shells, Stones, and Patches of Gravel,	11	0
4. Gravel with much *Melobesia polymorpha*,	1	0
5. Darkish Sand (the Whale Bed),	3	0
6. Dark, Muddy Sand, with *Pholas* in position, peaty towards the east end of section,	2	0
7. Dark-greyish Sand, the top only seen,	...	...
	26	0

A short distance further up the river there is a rusty bed of gravel, a few feet thick, resting on a peat-bed which lies in the bed of the stream, and probably both run under the dark-greyish sand-bed, No. 7. On the bank of the little stream, which enters the Pow Burn near Monkton Station, is to be seen, under a few feet of rusty gravel, a very compact peat-bed, which measures up to 10 inches in thickness, and readily splits into layers. This peat-bed

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is probably of the same age as that above-mentioned and the one at Williamfield—all three lying under rusty gravel.

The Whale remains which Mr. Downs discovered appeared to occupy the very same bed as that in which those of 1863 were found, but during my visit I picked up the epiphysial plate of a Whale's vertebra in a bed 5 feet higher up. From time to time other portions of Whale remains have been laid bare at the same locality by the denuding action of the river.

The above section also contains, both in the dark, muddy sand and in the grey sand, numerous burrows filled with light-coloured sand, similar to those already described in the Williamfield and Bartonholm sections, but apparently of greater variety of pattern in cross section, perhaps only owing to the better facility afforded here for studying them. The upper parts of the "great bend" section in which shells begin to appear are clearly beach-beds. We find in them thin, coal-dust patches similar to those often seen on the present beach. With these patches are mixed up the minute shells of ostracoda and foraminifera. There are also numerous "nests" of larger shells, *Mactra subtruncata* being conspicuous, often with united valves and empty interior. The stones in these sand-beds are just similar to what we find on the present seashore a mile opposite, where, during storms, many measuring up to 8 inches in diameter are hauled ashore by the larger seaweeds and left stranded on the beach. Throughout the section are also to be found, though sparingly, small nodules of chalk-flints. Seaweeds are great carriers of stones, and at certain seasons of the year fleets of them may be seen sailing along, each with a stone attached to it. A *Fucus* only 6½ inches in length, and weighing, after its surface moisture had evaporated, 3 drachms, I found was floating and carrying a stone of 12 drachms, or four times its own weight; and, as I have already pointed out, beds of gravel are often formed by seaweeds carrying and depositing stones in certain localities.*

Above the beds here is the district known as Shewalton Moor, consisting of sand dunes, with hollows between them covered with stones and gravel. This gravel covering has resulted from the aërial deformation of part of the top of the Raised-beach beds. After a certain quantity of the sand gets blown away, the gravel

* *Transactions*, vol. vi., part 2, 1882.

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and stones completely cover the remaining sand, and further aërial denudation is thereby prevented. On the seashore I occasionally find stones finely striated, this striation not having resulted from glacial action, but from the stones having been hauled by the large laminarian seaweeds along the sea-bottom. Such stones are only striated on their *sides*, and the seaweeds which had hauled them are often still attached to their ends. This being the case striated stones in Raised-beach beds cannot with certainty be ascribed to glacial action. In the gravel hollows between the sand-hills there sometimes turns up an occasional pebble of limestone, in the interior of which is a *Saxicava* shell, the only remnant of organic evidence that the beds in which this limestone occurred were of marine origin.

For a number of years past I have paid special attention to the vertical height to which the larger stones are carried up on the Irvine sea-beach by the waves during great storms, and I have never yet found this height to exceed 3 feet above high-tide mark, while the sands are assorted by the waves for perhaps 3 vertical feet higher. Of course, Irvine Bay receives great protection from the Mull of Kintyre, and is therefore not subjected to the full force of the Atlantic waves. There would not be much difference in this respect during the time the beds at the "great bend" were being formed, as the land at that time appears to have stood only about 40 feet lower than it does now.

In the lower part of the "great bend" section small tufts of vegetable debris are sometimes to be found, with an occasional hazel-nut, some seeds of plants, and a land-shell. The vegetable matter is evidently contemporaneous with the beds in which it is found, but compact, board-like pieces of peat, well rounded at the edges, evidently derivative, and occurring simply as pebbles, are often to be met with. They somewhat resemble the peat already noticed in the Williamfield section, and, like it, contain iron pyrites, which sometimes coats the vegetable remains as if they had been electro-plated. Some pieces of the peat contain seeds of the Bogbean, often so abundantly as to form divisional planes in the matrix. When the peat is first split open these seeds are of a brown colour, but they soon turn black. The *Pholas* which inhabited the muddy bed has often bored through these peat-pebbles. Sulphide of iron, or pyrites, is a substance which at an early period

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enters into the petrifaction of organic substances, and I have often found some of the foraminifera in these beds which had been converted into it.

The variety of the stones in the beds at the "great bend" is very great, in fact, I do not know any place in Ayrshire where such a variety has been collected into so small an area. For the most part they have been derived from Ayrshire rocks, the bulk being porphyrites, dolerites, and amygdaloidal traps, with a few West Highland schists, pegmatites, &c., interspersed amongst them, and they have all evidently been washed out of the Boulder-clay, as, so far as I have examined, the forty-feet Raised-beach beds contain no stones which have been carried by ice, except perhaps by river-ice.

A surface peculiarity of these forty-feet Raised-beach beds is to be seen in the district between Irvine and Troon—the manner in which the ground has been thrown up into long, curving ridges running roughly parallel with the present coast-line, certainly the most peculiar feature of the Raised-beach formation in the district. These ridges, where they are best developed, extend for a distance of about a mile and a half, and they are nowhere better preserved, or in greater number, than about half a mile to the south of Meadowhead farm-house. Commencing at the edge of what was once the Shewalton Moss, and walking at right angles across the ridges towards the shore, as many as twenty-six may be counted. That part of the Moss next the ridges is occupied by a hollow, and probably they may extend under the peat, but, of course, this cannot easily be determined. These round-backed ridges run from about 2 feet high above the intervening hollows, and where placed closely they resemble the old-fashioned ridges thrown up by farmers before tile-draining was adopted. The larger ones run up to 7 or 8 feet in height, and many can be seen extending as far as the eye can pick them out, some being exceedingly symmetrical and well formed. A few are double, that is to say, a large ridge sometimes has a slight depression along its crest, and they are occasionally seen to branch. The first is about 50 paces from the edge of the old Shewalton Moss, and the others, walking seawards, are passed as follows:—54, 12, 18, 19, 25, 11, 20, 48, 24, 25, 27, 29, 50, 33, 28, 41, 68, 39, 33, 54, 47, 70, 142, 170, 42, and 30 paces, respectively, measured from top to top at right angles to

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the ridges. Between the westernmost ridge and the sand-hills which skirt the coast there is a considerable area of almost level ground.

That these ridges were thrown up by the action of the waves I think there can be no doubt, the action of the wind being to destroy them, and in many places they appear to have been thus deformed. Perhaps, as they occupy what would be the stormiest position in the old bay where they were formed, a slightly greater admixture of gravel has given the portions which are best preserved a greater permanency than the more sandy parts, which have been destroyed by the wind. In fact, this district still appears to be a stormy locality, the winds finding free access through the gap to the north of Dundonald Hills; and the two farms of North and South Gailes have possibly derived their names from this peculiarity, one of them being situated near the north part, and the other near the south part, of the place where these long ridges are best seen.

I think we may gather from the way in which these ridges are arranged that during their formation a large amount of the material with which they were built up was brought down by the Irvine Water, and that there was perhaps at the same period a greater prevalence of periodic storms. These, with the land about 40 feet lower than it is at present, which would give greater sea-room and stronger sweep of wave, jointly account for the fact of their formation in this locality. There are no similar ridges now being formed along the present shore-line, and, from the large plain between the last of them and the sand-hills which skirt the coast, it is evident that none have been formed for a long time; while it should be mentioned that the two last formed are rather small ones, although many quite as small are to be found here and there amongst their number.

During the forty-feet Raised-beach period the Irvine Water must have entered the sea somewhere about Shewalton, and it would be tidal for a considerable distance above that. During the same period the Garnock Water would enter the sea near Kilwinning. In the neighbourhood of Kilwinning and Irvine the surface of the Raised-beaches forms large and very level plains, which at some parts are very sandy, and it is remarkable that more of the sand has not been blown up into dunes. The most hummocky parts are at Shewalton Moor, on the south side of the Irvine Water, and at "The Gofields" (Golf fields) now covered with grass, to the south

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of the town of Irvine, where the game now become so popular was played in the days of old until it was put a stop to by Government.

The outcrops of the Raised-beach beds along the lower reaches of the Garnock Water are not very extensive, but a few feet of rusty sands and gravels may be seen on the east side of the river below Snodgrass. A striking feature of the "great bend" section at Shewalton Moor is the large quantity of *Melobesia polymorpha* it contains, especially in the more gravelly parts. It is found coating the stones with a whitewash-like crust, and often envelopes them in brain-like masses to the thickness of an inch and a half.

Having visited this section a great number of times during the last twenty years, I am able to present an extensive catalogue of organic remains gathered from it. In this list I shall draw a comparison between the mollusca found in the section and those got on the opposite shore during the same period of time; as also those from the glacial shell-beds of which the position is below the Raised-beach beds. As there are no glacial beds exposed in the Irvine district, and as none were passed through in the Heather-house pit, I shall take the nearest localities where they have been met with, viz., in Stevenston parish, at Kilwinning, and at Troon. The nomenclature followed is that of Jeffreys:—

MOLLUSCA.

	Glacial Beds, Stevenston, Kilwinning, Troon.	*Raised-beach Beds, Shewalton Moor.*	*Present Beach, Stevenston to Troon.*
Helix rotundata (a land-shell),		Rare	
Cochlicopa tridens (a land-shell),	Rare		
Anomia ephippium,	Frequent	Common, small	Common
,, *aculeata*,		Rare	
Ostrea edulis,		Common, small	Frequent
Pecten opercularis,		Common, small	Scarce
,, *varius*,			Rare
,, *grœnlandicus*,		Rare, small	
,, *islandicus*,	Frequent		One valve, probably from a glacial bed
,, *maximus*,		Frequent	Rare
,, *septemradiatus*,		Rare	Rare
Mytilus edulis,	Rare, large	Frequent	Frequent
,, *modiolus*,	Very common	Rare	Rare
Nucula tenuis,	Frequent		
Leda pernula,	Common		

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MOLLUSCA.—*Continued.*

	Glacial Beds, Stevenston. Kilwinning. Troon.	*Raised-beach Beds, Shewalton Moor.*	*Present Beach, Stevenston to Troon.*
Leda pygmæa,	Rare		
,, *arctica*,	Rare		
Pertunculus glycymeris		Rare, eroded	Rare
Montacuta ferruginea,		Frequent	
Axinus flexuosus,	Very common	Rare	
Lucina borealis,		Common	Rare
Cardium fasciatum,		Scarce	
,, *exiguum*,		Rare	
,, *echinatum*,		Rare	Frequent
,, *nodosum*,		Rare	
,, *edule*,	Scarce	Common	Frequent
,, *norvegicum*,		Very common	Frequent
Cyprina islandica,	Very common, large	Scarce, large	Frequent, living specimens always small
Astarte sulcata, var. *elliptica*,	Common		
Astarte borealis,	Frequent		One valve, probably from a glacial bed
,, *compressa*,	Common	Frequent, small	
Venus exoleta,		Very common	Frequent
,, *lincta*,		Frequent	Frequent
,, *faciata*,		Common	Rare
,, *gallina*,		Very common	Common
,, *verrucosa*,			Rare
Tapes virgineus,	Rare	Very common	Rare
,, *pullastra*,		Frequent	Scarce
,, *decussatus*,		Scarce	Scarce
,, *aureus*,			Rare
Tellina squalida,		Scarce	
,, *balthica*,		Scarce	Rare
,, *fabula*,			Scarce
,, *tenuis*,		Frequent	Very common
,, *donacina*,		Frequent	
,, *crassa*,		Rare	Rare
,, *calcarea*,	Common, large		
Donax vittatus,		Scarce	Frequent
Psammobia tellinella,		Scarce	
,, *farröensis*,		Frequent	Scarce
,, *vespertina*,		Rare	
Mactra subtruncata,		Very common	Very common
,, *stultorum*,		Rare	Frequent
Lutraria elliptica,		Frequent	Frequent
,,		One specimen	
Scrobicularia piperata,		Frequent	Scarce
,, *alba*,	Rare		
,, *prismatica*,	Rare		
Solen ensis,		Rare, small	Common, large
,, *siliqua*,		Frequent, small	Common, large
Mya truncata,	Common		Rare, dead shells

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MOLLUSCA.—*Continued.*

	Glacial Beds, Stevenston, Kilwinning, Troon.	*Raised-beach Beds, Shewalton Moor.*	*Present Beach, Stevenston to Troon.*
Mya arenaria, -			Frequent
Thracia papyracia, -		Frequent	Scarce
Saxicava rugosa, -	Common, large	Frequent, small	Common
Pholas crispata, -	Rare, large	Frequent, large	Rare
,, *dactylis,* -		Rare	
,, *candida,* -		Rare	
Xylophaga dorsalis,		Rare	Frequent, in timber
Teredo norvegica, -		Rare	Frequent, in timber
,, - - -			Rare, in timber
Chiton marmoreus, -	Common		
,, - -		Rare	
Patella vulgata, -		Frequent, small	Common
Helcion pellucidum, -	Rare	Rare	Frequent
Tectura virginea, -	Very common	Rare	Rare
Puncturella noachina,	Common		
Emarginula fissura, -			Rare
Trochus helicinus, -		Rare	Rare
,, *magus,* -		Common	Frequent, dead shells
,, *ziziphinus,* -			Scarce
,, *tumidus,* -	Very common	Common	Frequent
,, *umbilicatus,* -			Frequent
,, *cinerarius,* -	Scarce	Common	Frequent
,, *grœnlandicus,*	Scarce		
Lacuna divaricata, -	Rare	Frequent	Scarce
,, *pallidula,* -			Scarce
,, *puteolus,* -		Rare	
Mölleria costulata, -	Rare		
Littorina obtusata, -	Rare	Frequent	Common
,, *rudis,* -	Rare	Rare	Frequent
,, ,, var. *saxatilis,* - -		Rare	Frequent
,, *littorea,* -	Scarce, large	Frequent	Common
,, *limata,* -	Rare		
Rissoa striatula, -		Scarce	
,, *reticulata,* -		Scarce	
,, *abyssicola,* -		Scarce	
,, *lactea,* - -		Scarce	
,, *costata,* - -		Rare	
,, *parva,* var. *interrupta,* - -	Common	Frequent	Frequent
,, *inconspicua,* -		Scarce	
,, *striata,* - -	Common	Frequent	
Skenea planorbis, -	Scarce	Frequent	
Homalogyra atomus,	Frequent	Frequent	Scarce
,, *rota,* -		Rare	
Cæcum trachea, -		Frequent	
,, *glabrum,* -		Common	Scarce
Turritella terebra, -		Rare	Rare

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MOLLUSCA.—*Continued.*

	Glacial Beds, Stevenston, Kilwinning, Troon.	*Raised-beach Beds, Shewalton Moor.*	*Present Beach, Stevenston to Troon.*
Scalaria turtonæ,			Rare
,, *communis*,		Rare	Rare
Odostomia nitidum,		Rare	
,, *unidentata*,	Rare		
Eulima distorta,	Rare		Rare
Natica catena,		Frequent	Common
,, *sordida*,			Rare
,, *montacuti*,		Scarce	
,, *alderi*,		Scarce	Common
,, *affinis*,	Frequent		
,, *grœnlandica*,	Frequent		
Aporrhais pes-pelecani		Rare	Rare
Velutina undata,	Common		
,, *levigata*,			Scarce
Cerithium reticulatum,	Rare	Common	Frequent
Purpura lapillis,		Scarce	Scarce
Buccinum undatum,	Frequent, small	Rare, eroded	Common, large
,, *grœnlandicum*,	Scarce		
Fusus antiquus,		Rare, eroded	Rare
,, *gracilis*,			Rare
Trophon clathratus,	Common		
,, *truncatus*,	Rare		
,, *clathratus*, var. *gunneri*,	Rare		
Nassa reticulata,		Frequent	Frequent
Defrancia purpurea,		Scarce	
Pleurotoma pyramidalis,	Frequent		
Pleurotoma violacea,	Rare		
,, *turricula*,	Rare		
,, *nebula*,		Rare	
Cypræa europæa,		Rare	Rare
Utriculus mammillatus		Scarce	
,, *truncatulus*,		Scarce	Scarce
,, *obtusus*,		Scarce	Scarce
Actœon tornatilis,			Scarce
Scaphander lignarius,			Frequent
Sepia officinalis,			Rare
Octopus vulgaris,			Rare

I have also collected the following fossils in the "great bend" section :—

Lepralia, several species.
Crisia eburnia.
Seropocellaria scabra.
Veruca stromia.
Balanus.

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Crab remains.
Ostracoda, a number of species. Many of the shells have a small hole bored through them.
Spirorbis communis.
Serpula, two species.
Echinus sphæra.
Amphidotus cordatus, sometimes entire, in the sand.
Foraminifera, a number of species, *Polymorphina lactea*, var. *fistulosa*, being large and fine.
Cliona gorgonioides (a sponge boring into oysters, *Pecten maximus*, &c.).
Melobesia polymorpha on limestone pebbles.
,, *calcarea* ,,
Chara seeds, evidently brought down by the river.
Corallina officinalis.
Horse bones.
Whale bones.

SUMMARY OF SPECIES IN THE FOREGOING LIST.

Marine Mollusca in the Glacial Beds of Stevenston, Kilwinning, and Troon,	53
Marine Mollusca in the Raised-beach Beds, Shewalton Moor,	97
Marine Mollusca on the Present Beach from Stevenston to Troon,	84
Boreal Shells in the Glacial Beds,	8

It will be seen that the genera *Ostrea*, *Pecten*, *Cardium*, *Venus*, *Tapes*, *Tellina*, *Donax*, *Psammobia*, *Mactra*, *Lutraria*, *Patella*, *Cœcum*, *Scalaria*, *Fusus*, *Utriculus*, and *Scaphander* are either totally absent or very poorly represented in the glacial beds. *Pecten islandicus* and *Tellina calcarea*, both now living only in the Arctic seas, are the sole representatives of their respective genera. Altogether there are eight species belonging to northern types which are either extinct or dying out in the British seas. Although I have called the section of strata at the "great bend," the Raised-beach beds, still this title can only be strictly applied to the upper part of it, as the lower has evidently been laid down on a sea-bottom. *Pholas* is confined to the muddy bed in its lower part, and is found standing in the position in which it lived. *Lutraria elliptica* is often to be seen in the erect position in which it lived, just at the top of the muddy bed, or sometimes a little higher. *Pecten maximus* is found in the lower part of the sandy bed, and the specimens are generally worn. *Venus exoleta* and *Tapes virgineus* are often got in a similar position

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with the valves united, and when got higher up they occur as single valves. *Venus fasciata* is common; *Lucina borealis* is got in the sand-bed. *Solen* is remarkably dwarfed compared with recent specimens on the shore opposite, *S. siliqua* seldom reaching 6 inches in breadth, and proportionally slender. Similar remarks apply to *Patella vulgata*. *Trochus magus* is large and fine in the lower part of the section, lying above, and sometimes in, the muddy bed. *Scalaria* is found lying in the sandy bed, of about the same size and in the same frequency as on the present shore. *Apporhais* is rare, but so it is on the present beach, although common in the bay in deep water. It may be remarked that at about a mile from shore the depth suddenly increases from 6 to 13 fathoms of water, which may prevent this shell from being often washed ashore.* It is remarkable that *Buccinum undatum*, now so common on the beach after every storm, should be so rare in the Raised-beach beds, having been frequent in the glacial beds below them. In fact in the former beds carnivorous gasteropods are scarce, and few shells which have been bored by them are found. *Cyprina islandica* is very common in the glacial beds, frequent in the Raised-beach beds, and still frequent on the recent beach; living specimens tossed ashore are always small, though large single valves are often hauled out of the deep water by sea-weeds. *Mactra subtruncata*, a shell rare in the south of England, is abundant both in the Raised-beach beds and on the present shore. It is remarkable that *Mya* has not turned up in the Raised-beach beds, although one of the species is common in the glacial beds, and the other is frequent in the estuary of the Garnock. Both *Trophon* and *Pleurotoma*, with one exception, are absent from the Raised-beach beds, and from the present shore, although five species and a variety are got in the glacial beds. *Saxicava rugosa* is frequently found at the "great bend," inside pieces of *melobesia*-covered limestone into which it has burrowed, the same pebbles being generally riddled by the twisting burrows of sponges.

Many of the shells at the "great bend" are in an exceedingly fine state of preservation, and some are even found with the epidermis and the colour-markings. Some of them are crusted over with sand in a similar manner to that in which they are found in older formations, and some are iron-stained, and sometimes blackened.

*See *Proceedings Nat. Hist. Soc. of Glasgow*, 1892, p. 243.

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Some portions of the sand have also been formed into nodules, generally of a longish shape.

That the Boulder-clay does not lie as a "plain of marine denudation" under the Raised-beach beds of the district is very clearly seen in the Irvine Water, where, at a distance of 150 yards above the bridge of the Kilmarnock Branch Railway, a ridge or drum of it is seen in section on both sides of the river, the top being covered by a few feet of the Raised-beach beds, and its denudation has supplied a large number of boulders which form quite a feature in the bed of the stream. Another ridge of it is crossed by the Garnock Water, where it is tidal, at Dykehead, near Kilwinning. Higher up the country ridges and drums of Boulder-clay, free from any capping, are quite a feature in the landscape. Professor James Geikie refers* to certain deposits of sand and gravel "heaped up into mounds" in the lower reaches of the Lugton and other streams. When he wrote his book, I daresay this was about all that could be said with reference to the long, mound-like deposits about Kilwinning, in Eglinton Castle policies, and extending to near Dreghorn, as then only a few openings into them, from which gravel was extracted, could be examined. But recent sections in both the above-mentioned localities have shown that these mounds are really in great part composed of Boulder-clay covered over with deposits of sand and gravel.

The section made by the cutting for the Caledonian Railway across the long ridge on which the town of Kilwinning is situated was as follows:—On top and sides of the Boulder-clay mound were a few feet of sand and rusty gravel, the top of the clay under the sand being penetrated by innumerable holes of *Mya truncata* with the shells still standing in them. On the south side there was a bed of coarser rusty gravel measuring up to about 12 feet in thickness, and on the north side an opposing bed of yellowish sand which ran under a bed of dark muddy sand with *Tellina calcarea*, *Cyprina islandica*, and other fossil shells, and this is the only instance in which I have seen these Boulder-clay-ridge sands overlaid by beds containing arctic shells. It is worthy of special remark that the *gravel*-bed was on the side of the Boulder-clay ridge exposed to the sea, and the *sand*-bed on its sheltered side. Other openings about Kilwinning have proved the existence of the Boulder-clay-ridge under the gravel, and a similar long section in

* "Great Ice Age," 2nd ed., p. 221.

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Eglinton Castle policies also showed a ridge of Boulder-clay under rusty gravel. The gravel- and sand-covered flanks of the ridges have probably, in great measure, been derived from the partial marine denudation of the Boulder-clay itself, and many of the pebbles in these gravels are so much decomposed as to be easily crushed between the finger and thumb. Sea-gravel extends to a height of 190 feet above sea-level, and is fairly thick in the district of Dreghorn. The gravelly fishing banks in many parts of the Firth of Clyde have probably had a similar origin to that of those ridges described above.

There is a section of some interest in the railway cutting north of the Kilwinning station of the Glasgow & South-Western Railway, which was exposed when the recent extension of "lyes" took place—

	Ft.	*In.*
1. Yellow Sand, with Thin Bands of mahogany-coloured Clay,	4	0
2. Muddy Sand, (containing a boulder 20 inches in diameter.)	2	0
3. Mahogany-coloured Clay, with partings of ripple-marked Sand, ...	3	0
4. Muddy Clay, ...	4	0
	13	0

In these beds there appeared to be a total absence of organic remains. They were much thinner and sandier towards the south, where, passing through them, there were some small faults, as sharply defined as if they had been formed in solid rock. There were also six masses of Boulder-clay which had evidently been squeezed up amongst the gravel, and so contorted, by the stranding of an iceberg.

When the excavation for the Troon gasometer was made in 1883, I obtained thirty-two species of mollusca from the sandy clay which was dug from it. From the occurrence of *Astarte borealis*, *A. sulcata* var. *elliptica*, *Tellina calcarea*, and *Pecten islandicus*, this bed evidently belonged to glacial times. When the Perceton pit, next the Annick Water, was being sunk, there was sent up a lot of clay with well-striated stones and a few boulders. In this clay were a large number of shelly fragments, the large hinges of *Cyprina islandica*, which were rounded, scratched, and polished, being conspicuous. There could be no doubt that this clay, having been forced over a glacial shell-bed, had been crushed up and mixed with it and its contents. The height of the top of the clay was about

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sixty feet above high-tide level. On the side of the Annick Water is to be seen a Boulder-clay with striated stones and fragments of shells, probably the same bed which was passed through in the Perceton pit.

The water oozing from the Raised-beach beds is often highly charged with iron oxide, derived from the decay of the contained iron-bearing minerals, and to such an extent as to have given a name to one of the streams—the Red Burn—which flows over them. This substance is often a great trouble to farmers, necessitating the lifting and cleansing of the drain-pipes in some localities about every five years. An irridescent oily-looking substance is often seen floating on the surface of the water in the ditches, and is possibly derived from the decay of the animal matter in the sand and mud. It may be mentioned that no peat-beds have been found in the district under any bed which contains boreal shells.

Should the land again sink for a distance of 50 feet, the waves would return and cover up the thick peat-bed which forms Shewalton Moss, depositing on it beds of sand and gravel in the manner they have at least twice already done.

SUMMARY.

There is in the Kilwinning and Irvine districts a series of what are called Surface Beds, which I have grouped as follows, and their examination, I think, bears out the following conclusions:—

I.—Boulder-clay (ground moraine), formed by thick land-ice, has been carved into drums* and ridges, by a *second* glaciation up to about 200 feet above sea-level. Higher up country the drums disappear. These drums and ridges are both preserved under the higher gravels, which extend to 120 feet above sea-level, as well as under the forty-feet Raised-beach beds, and even lower, showing that they had not been subjected for any length of time to the denuding influence of the waves.

II.—Interglacial Beds, a little to the north of Kilwinning, and described in my paper on "The Great Ice Age in the Garnock Valley,"† were deposited when the ice had melted from this part of the country.

* "Drum" is here used for a small knoll-like hillock.

† "The Great Ice Age in the Garnock Valley."—*Transactions*, vol. ix., part 1, p. 151.

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III.—Perceton Boulder-clay, mixed with shelly debris, was produced by land-ice, probably by that which formed the drums and ridges. This second glaciation appears to have been a pretty severe one. It was no mere matter of valley-glaciers, and it may have effectually destroyed any remains of high-level shell-beds which existed in the district. There is a strangely persistent gravelly parting in the Till, well seen in the "tir" of the Monk-redding quarries, which appears to be the line of demarcation between the old Till and the second glaciation Till, both of which are typical ground-moraine. The gravelly bed looks as if it had been drawn out or spread out from a much thicker bed, and is placed just about where the drums terminate—going up country.

IV.—Stratified Iceberg-Boulder-clay at Smithstone, in the Heatherhouse Pit and at Ardrossan New Docks, found about 40 feet thick at the 200-contour level, when the Ardrossan new reservoir at Mill Farm was being made, and showing a depression of the land of over 200 feet. This deposit has been formed by materials dropped from icebergs, and contains boulders up to 4 feet in diameter.

V.—High-Level Sands and Gravels are mostly of a rusty colour, rise to 120 feet above sea-level, and sometimes contain boulders 3 feet in diameter. These beds were deposited when there was floating ice in the Clyde.

VI.—Beds of Clay (*Leda*-clay), Sand and Gravel, from 33 feet below sea-level to 70 feet above it, contain a number of shells which now live only in the Arctic ocean. These beds are seen resting on the lower beds of the high-level sands and gravels at Kilwinning.

VII.—Forty-feet Beach Beds contain at some parts two beds of peat which have accumulated *in situ*, both of these having been depressed below sea-level and again elevated, with numerous organic remains, all of recent British types, including those of the horse and the Whale. The temperature during their deposition must have been much the same as, if not milder than, it is at present. The large oak-trees found under the peat-mosses higher up the country probably lived during this period.

VIII.—Twenty-five-feet Beach Period is represented by terraces, and possibly by the shell-beds at the Ardeer Sandstone quarry and at Penny Burn. The ancient shell-mounds of the

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Ayrshire coast were accumulated by man probably at the close of this period.

IX.—Recent Deposits of Impalpable Mud are taking place in the Clyde below 30 fathoms, with *Nucula*, *Leda*, &c. Similar deposits containing these genera of shells are found in the district as early as Carboniferous times. There are also beach-deposits of sand, gravel, and shells, mixed with stones which have been hauled ashore by seaweeds, probably from former beach-beds now sunk under the waves.

"Footprints on the sands of time."

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No. VI.—On Australian Coals. By Thomas Steel, F.C.S., *formerly of Greenock.*

Communicated by John Young, LL.D., F.G.S.

[Read 9th March, 1893.]

The series of specimens which I exhibit is from the principal coalfields of Australia, and, with the accompanying analyses, is fairly representative of the coals of the different districts.

First in importance for quality of coal, extent of the deposits, and facilities for shipping, together with central situation of the field, are the coals of Newcastle, New South Wales.

This is a true Carboniferous coal, highly bituminous, and occurs in strata belonging to the upper Carboniferous system. There are a number of distinct seams in this field, all of much the same quality, but separated by a considerable thickness of poor shales and kindred rocks. The mines are situated in close proximity to Port Hunter, on which is the town of Newcastle, a short distance along the coast to the N.E. of Sydney. Port Hunter is a fine sheltered and land-locked bay, having a good depth of water and efficient means for loading large steamers with despatch and economy. For steaming purposes and general use the coal is considered as the standard coal of Australia. There is a considerable number of pits belonging to different companies, most of which are named after pits and places in Britain—the Lambton, Hetton, Burwood, Stockton, Wickham, Ferndale, Bullock Island, Dudley, Wallsend, and Wearmouth being amongst the leading mines of the field. This district has suffered severely in recent years through the numerous disastrous disagreements between the workmen and their employers. The result has been the driving away to other markets of established and prospective users of the coal, and the output has thereby been very seriously curtailed. During the great strike of 1890, small coal from this district was selling wholesale in Melbourne at £2 10s. to £3 per ton, and was unprocurable even at that figure, while in the suburban districts of the city as much as £4 10s. was paid for household coal. So great was the coal famine that the heaps of waste dross from about the pitheads were shipped to the cities

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and sold for three times the normal price of good coal. The usual cost of Newcastle coal, delivered at the ship's side in Melbourne, is from 18s. to 21s. per ton for round, and 14s. to 16s. for small coal. Free on board at Newcastle, the rates are usually 11s. for round, and 6s. per ton for small coal.

Next in importance are the mines at Bulli, Wallongong, and Mount Kembla, on the coast in the south of New South Wales. These coals appear to be of Permian age, are non-coking, and are usually high in ash. The deposits are of considerable extent, but a great drawback is the absence of proper shelter for vessels, the coal having to be shipped from jetties on the ocean beach. It is almost entirely used for steam and other industrial purposes, and is very friable, so that in winning a large proportion of small is produced. When burnt in ordinary boiler furnaces it requires a good deal of manipulation in order to get full duty out of the fires. As it is a slow-burning coal, the best result is got by working a thick fire, and keeping the surface frequently stirred. Mixed with Newcastle "slack," it is greatly improved, and gives very satisfactory work, the soft Newcastle coal keeping the fire more free and open, and giving a flame. The cost of the "slack" coal from these mines, usually known as the Southern Mines, is 11s. to 14s. per ton at the ship's side in Melbourne, the cost at the pit being 3s. to 3s. 6d.

The coals from about Brisbane, Queensland, are a good deal like the southern coals of New South Wales, but as I have only had a limited experience of using them, I cannot properly compare them with the others.

In Gippsland, Victoria, there are very extensive deposits of a soft brown-coal or lignite, stated to belong to the Oolite, and of which I have here a representative series of specimens. A good deal of attention has been given to exploiting these fields during the last two or three years, but, as yet, the coal cannot be said to have gained much public favour. Consisting as it does of a barely-formed lignite, it is very spongy and moist when freshly cut, and contains varying amounts of water up to over 40 per cent. When dry it is very friable, and breaks up in handling, forming much small dust and waste. The Victorian Government has had large samples sent to Germany, where it has proved very suitable for compressing into briquettes, so extensively manufactured from the German

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brown-coals, and it is probable that its use in this form will extend when it can be produced cheaply enough. The most striking feature about its composition as disclosed by analysis, apart from the high percentage of water, is the very large proportion of volatile hydrocarbons, and experiment shows it to yield much gas of a low illuminating power when subjected to distillation. In the fire it burns very much in the same manner as peat. Numerous small pieces of a fossil resin, called *retinite*, resembling the *ambrite* of the New Zealand coals, occur in some samples of this lignite.

The coals of New Zealand appear to be of Cretaceous age, and vary exceedingly in quality and composition. The best of them is that of Westport, the ash of which is generally under 2 per cent. Very extensive mining is carried on at Kamo, near Whangerei, and at Bay of Islands, and some very thick beds or seams occur at Huntly, on the Waikato River, all of which districts I have visited. The sample which I exhibit is a handsome, glossy lignite, resembling ebonite. It is from Taupiri, Waikato River.

There are deposits of coal in Tasmania, about which I am not in possession of any information, but the samples which I have seen, the analyses of which are stated herewith, bear considerable resemblance to the southern coals of New South Wales.

During the labour troubles of 1890, when work was suspended at all the Australian mines, shipments of coal, for the gas works, were taken to Melbourne from Japan. Samples which I obtained are exhibited, and the analyses stated along with the others.

I have appended an interesting table showing the quantities and value of coal and kerosene shale mined in the Australasian colonies during nine years up to 1886. This table is from one accompanying a paper on "The Development of Mining in Australasia," read by Mr. S. Herbert Cox, F.C.S., F.G.S., before the 1887 meeting of the Australasian Association for the Advancement of Science.

I have to acknowledge the assistance of Messrs. H. L. Whitaker and W. E. Appleby in the analytical examination of the samples of coal.

The series of specimens exhibited has been deposited in the Hunterian Museum, University, Gilmorehill, Glasgow.

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NEWCASTLE, NEW SOUTH WALES (Round Coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
2·74	30·53	57·97	8·76
1·30	35·50	58·27	4·93
1·25	35·75	58·68	4·32

NEWCASTLE, NEW SOUTH WALES (Small Coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
3·06	32·41	55·59	8·94
2·92	33·10	54·38	9·60
4·70	32·70	52·99	9·61
3·89	31·81	52·79	11·51
3·87	32·41	54·14	9·58
3·35	33·30	51·62	11·73
2·95	33·85	53·82	9·38
3 25	34·65	55·23	6·87
3·00	34·80	55·20	7·00
3·05	34·90	54·60	7·45
3·61	33·69	54·40	8·30
1·90	34·43	55·27	8·40

WOLLONGONG AND BULLI, NEW SOUTH WALES (Small Coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
2·82	24·58	63·35	9·25
1·28	17·96	69·44	11·32
1·36	17·85	66·19	14·60
1·24	21·35	66·17	11·24
0·96	20·84	63·70	15·00
1·80	19·81	63·81	14·58
1·32	21·39	65·65	11·64
1·54	17·15	69·52	11·79
3 13	18·95	64·90	13·02
1·28	20·57	67·52	10·63
2·08	19·53	68·01	10·43
1·10	19·12	68·02	11·76

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MOUNT KEMBLA, NEW SOUTH WALES (Small Coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
1·39	21·64	63·89	13·08
1·95	22·15	61·07	14·83
2·76	23·86	62·36	11·02
3·48	22·55	61·51	12·46
3·03	22·82	62·51	11·64
2·75	22·49	59·27	15·49
2·93	22·52	63·50	11·05
2·48	22·95	62·42	12·15
2·05	21·40	61·55	15·00
3·10	23·63	62·66	10·61
2·05	23·10	60·75	14·10
2·50	23·05	62·35	12·10

BRISBANE, QUEENSLAND.

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
*3·74	28·76	59·01	8·49
†2·68	30·02	57·61	9·69

GIPPSLAND, VICTORIA (Brown-coal).

Sample Marked.	Analysis.				Calculated to Dryness.		
	Water.	Volatile Hydro-carbons.	Fixed Carbon.	Ash.	Volatile Hydro-carbons.	Fixed Carbon.	Ash.
A_3,	22·59	37·64	37·91	1·86	48·63	48·97	2·40
B_3,	25·60	35·80	35·89	2·71	48·12	48·24	3·64
B_3, woody portion,	25·31	35·24	37·91	1·54	47·18	50·76	2·06
B_3, coal portion,	25·62	36·94	34·41	3·03	49·67	46·26	4·07
C_3,	33·85	30·11	32·65	3·39	45·52	49·36	5·12
D_3,	25·18	32·73	30·22	11·87	43·75	40·39	15·86
E_3,	29·80	31·54	29·79	8·87	44·93	42·44	12·63
F_3,	24·30	31·93	34·64	9·13	42·18	45·76	12·06
G_3,	38·16	26·97	30·93	3·94	43·61	50·02	6·37

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TAUPIRI, WAIKATO RIVER, NEW ZEALAND (Brown-coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
12·60	38·40	47·50	1·50

BAY OF ISLANDS, NEW ZEALAND.

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
5·00	39·35	46·32	9·33

TASMANIA (Brown-coal).

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
5·98 8·69	22·20 35·94	57·26 49·14	14·56 6·23

* Small coal. † Large coal.

JAPAN.

Water.	Volatile Hydrocarbons.	Fixed Carbon.	Ash.
†1·77 *1·87	31·84 34·08	62·76 57·00	3·63 7·05

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OUTPUTS OF COAL AND SHALE RAISED IN DIFFERENT COLONIES.

Year.	New South Wales.		Victoria.		Queensland.		Tasmania.		New Zealand.		Totals.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
		£		£		£		£		£		£
1878	1,599,868	978,147			52,580	21,272	12,311	10,464	162,218	89,219	1,826,977	1,099,102
1879	1,615,900	1,017,809			55,012	22,750	9,514	8,086	231,218	127,169	1,911,644	1,175,814
1880	1,485,381	660,062			58,052	24,573	12,219	10,386	299,923	164,957	1,855,575	859,978
1881	1,803,118	643,996	No details.	No details.	65,612	29,033	11,163	9,488	337,262	185,994	2,217,155	868,511
1882	2,157,347	1,033,079			74,436	33,603	8,803	7,482	378,272	209,049	2,618,858	1,283,213
1883	2,571,707	1,292,803			104,269	44,927	8,872	7,526	421,764	231,970	3,106,612	1,577,226
1884	2,780,727	1,375,253			129,980	54,160	7,194	6,381	480,831	264,457	3,398,732	1,700,251
1885	2,906,325	1,403,452			209,698	87,228	6,654	6,685	511,063	281,084	3,633,740	1,778,449
1886	2,873,738	1,403,140		21,048	228,656	95,243	10,391	6,898	534,353	298,894	3,647,138	1,825,223

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No. VII.—On an Alleged Bed of Shells, at High Molmont, near Galston, between 400 and 500 feet above sea-level.

By John Smith.

[Read 9th March, 1893.]

It is now several years since I was first informed by Mr. David Beveridge, of Kilmarnock, that there was a shell-bed at High Molmont, near Galston. He had never seen the shells himself, but got his information, when casually talking about fossils, from Mr. James Vallance, an engineman, who resided for a number of years in High Molmont Cottage. During his residence there Mr. Vallance's children were constantly bringing into the house, as playthings, shells which they said they got in the sand-pit on the opposite side of the road. It need scarcely be said that most people take very little interest in objects of natural history, and Mr. Vallance was no exception to the rule, as he never thought it worth his while to go into the sand-pit to look at the shells for himself. About two years ago I paid him a visit, and got from him a statement as to the shells, similar to that he gave Mr. Beveridge. The old sand-pit had been exhausted, at least so far as it could be worked from its nearness to the road, and from water rising in the bottom of the opening. A new one, some two hundred yards from the old one, had since been opened up. It is run into a hillock, which, from remnants left at one of the sides, appears also to have been the case with the former one.

Last year I went to have a look at the new sand-pit, and met a carter on the road who was in the habit of taking sand from it. He informed me that there was a bed of shells in the right-hand corner, but that in the meantime it was covered up by a fall of the face. On reaching the pit I found this to be the case, and as it would have been the work of days to have bared the face, I did not attempt it, but dug a hole as near it as possible, and cleared off the debris, so that I made a complete section 14 feet deep. About 20 yards north of where the fall had taken place, there was also a good working face of sand. Here a man was working, but I found he had not had much experience of the pit. In neither of these places did I find any shells, and in some material which I took away and examined microscopically, no organisms of any description were to be found.

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The section at that time was as follows :—

	Feet.
1. Soil,	1
2. Reddish Boulder-clay (ground moraine of the second glaciation) varying much in thickness, but not deeper than	5
3. Muddy sand, with a few thin laminæ of fine reddish Clay,	3
4. Grey sand,	5
5. Gravel with water, the top only seen.	–
	14

The muddy sand-bed, No. 3, was considerably contorted in parts, evidently by the ground moraine having been shoved over it.

In the beginning of February of this year [1893], with Mr. Beveridge and Mr. Downs of Irvine, I again visited High Molmont for the purpose of making further explorations. We first saw the farmer, Mr. Howie, of Meikle Maxwood, on whose ground the sand-pits are, and he informed us that in the old working, now levelled and restored to an agricultural state, he had often seen thin beds of shells. We opened a hole in the new pit, and dug down till we came to water, the section cut through being much the same as the lower part of the one already given, but without success, as no shells were found.

The manner of getting the sand is now different from what it used to be. A hole is dug, and as much sand as possible taken out. The adjoining waste stuff on the top is then thrown into the hole and the good sand beneath taken out, this excavation in its turn serving to hold more rejected material. By this method of working there is no provision left for drainage, so that the water rises and falls in the sand according to the state of the weather.

We next dug a hole at the side of the old pit near the road, at first passing through muddy sand, ultimately reaching sand, and then gravelly sand with water, at a depth of about 12 feet from the original surface. No shells or other organisms were got in this cutting more than in the previous ones; so that, so far as my explorations have gone, the subject remains just where I took it up. In bringing it before the Society I do so for the purpose of drawing the attention of the members to the spot, for, from what I have seen at High Molmont, the section, though on a smaller scale, has a striking resemblance to the top part of the shell-bearing clay at Clava. Of course, non-conchologists sometimes mistake strange

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things for shells; but it is difficult to imagine what the engine-man, the carter, and the farmer could have mistaken for them, supposing no shells were there.

To the south-east of High Molmont, near Molmontend, there is another roundish mound, at about 600 feet above sea-level, and I was told by the farmer that it also is composed of sand, and is very much larger than the High Molmont one. From the sandy nature of the field between the sand-pit and the Burn Anne Water (of jasper fame), there appear to have been considerable deposits of sand in the district, which are now much spread out on the lower sloping grounds, quantities having no doubt been carried away by the second glaciation, and by sub-aërial denudation. The mounds at High Molmont (from which the place in all likelihood took its name) have been protected by their capping of Boulder-clay of the second glaciation. It only remains further to be said that High Molmont Cottage has lately been demolished, and the land on which it stood restored to an agricultural state.

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No. VIII. On the Calderwood Limestone and Cementstone, with their Associated Shales. By James Neilson, V.P.

[Read 9th March, 1893.]

The strata to which I wish now to direct your attention are the Limestone and Cementstone, which have been so extensively worked in the neighbourhood of East Kilbride, and which are generally known as the Calderwood Limestones. It is no part of the proposed scope of the present paper to give a particular account either of their geological position, the area over which they are spread, or of their fossil contents. All these subjects have already been treated of more or less exhaustively by many authors in many papers, prominent amongst them being the Rev. David Ure in his "History of Rutherglen and East Kilbride." Bearing the date of 1793, the present year is the centenary of its publication, and as the author may be regarded as the father of Scottish Carboniferous geology and paleontology, it is to be hoped that such an opportunity will not be allowed to pass without any attempt to honour his memory.*

These strata have also been treated of in various papers read before this Society, and printed in its *Transactions*, including, among others, A Catalogue of Carboniferous Fossils of the West of Scotland, by Messrs. Young and Armstrong,† where short descriptions of the localities are given, and the general character of their fossils is indicated.

The most important paper upon the district, however, is the one by our respected corresponding member, the late Mr. Andrew Patton, which was accompanied by an admirable list of fossils drawn up by our esteemed member, the late Mr. James Coutts.‡ These beds are also described, and a list of the fossils given, in the "Explanation" to Sheet 23 of the Geological Survey of Scotland.

* Notwithstanding this timely reminder, no movement was made to carry out the author's admirable suggestion, and Ure's memory still waits the more general recognition which it is certain some day to receive. [Ed.]

† *Transactions*, vol. iii., supplement; afterwards republished in a separate form with many additions in 1876.

‡ "Geological Observations in the Parish of East Kilbride, Lanarkshire. With two Sections (Plate XIII). By Andrew Patton, Corresponding Member. With a List of Fossils, compiled by James Coutts." *Transactions*, vol. vii., p. 309.

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But yet with all this long-continued work there seems to be still a want. In all these papers we appear only to know the rocks and their contents at a distance, and my desire is to get more on speaking terms with them, as it were, and to learn many minute points which come only with increased familiarity. I wish, in short, to attempt in some measure to read the life-story of the fossils, and from it to deduce the conditions under which the strata containing them were laid down.

For convenience of reference I shall reproduce the following section from Mr. Paton's paper already referred to:—

	Ft.	In.
Dark Shale, - - - - -	17	6
Roman Cement, - - - -	0	11
Shale, - - - - - -	7	0
Limestone, - - - - -	1	6
Fossiliferous Shale, - - - -	2	6
Limestone, - - - - -	4	0
Total, - -	33	5

The best example of this section is at Limekilns quarry, where all the beds are visible.

The limestones of this district appear to have been wrought from an early date,—long before Ure wrote—and they have been worked continuously since till within the last few years. Owing, however, to the cheapness of carriage, both by sea and rail, and the consequent flooding of the market with Irish lime and English cement, neither the Calderwood limestone nor cementstone quarries have lately been in operation.

The "Roman cement" does not appear to have been known in Ure's time (1793), but the strata which produce it have been extensively worked since then; and its manufacture formed quite a flourishing industry in the early days of this Society's existence, though it afterwards gradually dwindled and finally died out, in this locality at least. Some steps have, however, been lately taken with a view of opening a new limestone quarry in the district, though from the fact that the English product, known as "Portland cement," is better, and, in the long run, cheaper, I fear "hic jacet" may be written over the unworked remains of the East Kilbride cementstone. It is rather melancholy that

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a change, which may benefit the country at large, should bring hardship and even ruin on a respectable and industrious community; yet there appears to be no help for such a state of matters. It yields a forcible illustration of the Darwinian theory of the survival of the fittest, and of the old proverb, that "the weakest goes to the wall." *

Limestones.—These rocks differ little from the majority of the lower limestones, are of a dark bluish colour, and contain a few fossils, of which the most common is *Productus giganteus*, while *Nautilus* and *Poterioceras* of large size are also found in them. They are clearly of marine origin, and have been deposited in comparatively pure water. Probably they have been of slow growth, and the vast majority of their inhabitants has died out without leaving a trace behind. In some localities there is present a thin band of coralline limestone, principally made up of the remains of *Lithostrotion fasciculatum*, but in most places this is absent.

Limestone Shale.—The fossiliferous shale between the two posts of limestone is one of the most remarkable beds to be found. It is crammed with fossils, and if quantity, rather than quality, be desired, they may almost be collected with a shovel. There is no mistaking this bed; it has been the happy hunting-ground of West-country geologists from David Ure onwards, and although the old shale-heaps of Boghead, Newfield, and Capelrig have been constantly searched from time immemorial, they still appear to be an exhaustless treasure-house for the younger generation of fossil collectors. The more modern pits at Dikehead and Kirktonholm yield the fossils in their natural position in the shale.

It was from Dikehead that our then Vice-President, Mr. (now Dr.) John Young, F.G.S., was able to expose the poriferous faces of the polyzoa, by a process of running melted bitumen on the face of the slab containing the organism, and afterwards dissolving off in water the shale which enveloped the pore-bearing faces of the fronds.†

This shale is very rich in the remains of crinoids, small corals,

* The working of the cementstone is still carried on at Orchard, near Giffnock, and at Arden, near Barrhead. [ED.]

† *Proceedings Nat. Hist. Soc. of Glasgow*, vol. iii., page 207.

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polyzoa, entomostraca, and foraminifera, all in the finest state of preservation, and many of these fossils form most beautiful objects for the microscope. Numerous examples of species from this bed have been figured in various works.

The encrinites, as is unfortunately too often the case in the Scottish beds, are mostly divided into short segments, or single oscicles or beads, and a quantity of these sufficient to form a necklace may easily be collected on a very short visit. In this form they have been called St. Cuthbert's Beads, and were referred to by Sir Walter Scott in his poem of Marmion.

> "On a rock at Lindisfarne
> St. Cuthbert sits, and toils to frame
> The wave-worn beads that bear his name."

Ure figures several varieties of these oscicles with the central canal of different shapes—some round, others with two, three, four, or five arms, the latter giving a beautiful star-like appearance to the central aperture. The two-armed varieties are generally found in lateral stems which branch off the main one, while the three-armed are very rare, and I had almost given up hope before I found any examples. But here is a specimen, showing six arms or rays, which seems to be very uncommon, as I have never seen another.

Although the encrinite stems are generally in so fragmentary a condition, it is not uncommon to find the cup-like bodies which form the heads, still having several of the plates in position. These beautiful objects are generally looked on as prizes by collectors.

The mollusca are, as a whole, rather poorly represented here, but *Discina* and *Crania* are got in greater abundance and of larger size than elsewhere, the former sometimes showing colour-bands. The most notable shell is probably *Chonetes Laguessiana*, which is found largest and best at Capelrig, many of the specimens showing remains of the colour-bands. It is not uncommon to find specimens in which the valves may be separated, although no thicker than a sheet of writing paper, yet the interiors of both valves show the muscular impressions beautifully preserved. The muscular impressions of several other species of brachiopoda are also found here in fine condition. The following eight species of this group occurring in this bed are figured by Davidson

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in his papers on Scottish Brachiopoda* — *Athyris ambigua, Spirifera trigonalis, Chonetes laguessiana, Productus longispinus, P. scabriculus, Crania quadrata, Discina nitida,* and *Lingula mytiloides.* In all nearly 130 species are recorded from this bed by the Geological Survey.

Fish remains are rare in this stratum, and there is nothing calling for special remark regarding them.

Let us now try to summarize the conditions under which these strata have been deposited. The underlying limestone is of purely marine origin, formed either far from land, or at least in pure water, and probably deposited very slowly. The shale bed has been formed of mud from some estuary, and the change may have been brought about by an upheaval of the land, or by the gradual silting up of the estuary, which would cause the mud-laden currents to be carried further out to sea. The former theory is the more probable, as in the latter event the limestone might be expected to pass gradually into shale. The deposition appears to have been very gradual, the sediment being of the finest character, and never in sufficient quantity to render the water muddy, otherwise it is probable that many of the true marine types would have been destroyed.

Cementstone and Shale.—The next beds in order, viz., the cementstone, with its overlying and underlying shales, form a striking contrast to the strata just spoken of. Those were literally crammed with fossils, and a couple of visits would give one a pretty fair idea of their entire fauna, but here we find the fossils are much more sparely distributed, and many of the most interesting forms occur only at rare intervals, consequently a thorough knowledge of their fossil contents can hardly be acquired by the ordinary flying visits of members of a society such as ours.

What was required for their investigation was a man constantly on the ground, and here science was fortunate in the presence of our corresponding member, the late Mr. Andrew Patton, manager for Messrs. John Brown & Co., who worked the cementstone at Kirktonholm, Glebe, Limekilns, and Burnbrae quarries, and

* "The Carboniferous System in Scotland, characterised by its Brachiopoda," published in *The Geologist*, vols. ii. and iii., 1859, 1860. These articles were afterwards republished as a small volume under the title of "Scottish Brachiopoda," 1861.

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also for some time the limestone at Limekilns and Kirktonholm. He was a North of England man, of very quiet and unassuming disposition, a most accurate and intelligent observer, and possessing the qualities of independence and integrity in a high degree. His observations have been the means not only of recording the fauna and flora of the beds under notice, but also of adding very considerably to the number of species known to science, more especially in the classes of phyllopod and podopthalmate crustaceans, and the selachian fishes. To such an extent are we indebted to Mr. Patton's labours in this field that these beds now stand unrivalled as regards the record of these groups, not only in the West of Scotland, but probably in the general distribution of the Carboniferous system.

The East Kilbride cementstone presents phenomena I have not met with elsewhere (although, I believe, a bed with some similarities has been observed in the East of Scotland); in fact it is of genuine estuarine origin. The word "estuarine" has been applied very loosely to beds, which their fossil contents show to have been laid down in fresh water, and the term has consequently been applied to the whole of the upper coal measures, the middle ironstone and coal series, and to numerous beds in the limestone series, and the calciferous series—the coal itself, of course, excepted. So far as I can make out, those beds possess no *positive* estuarine evidence, and the name has only been given them to get quit of the difficulty of admitting the existence of fresh-water lakes large enough to hold the various coal-fields.

Meanwhile, leaving this controversial point on one side, let us look at the conditions under which estuarine beds are deposited at the present day. Some of the great rivers are reported to spread their deposits over areas of hundreds or even thousands of square miles, and wherever the channel gets much wider and larger than the river requires for its ordinary flow, so that debris is deposited, there the estuary may be said to commence, and there will be deposited the remains of vegetation and other debris of the land. But at intervals this debatable ground will be invaded by the sea, bringing with it marine forms of life, which will from time to time be deposited and covered up along with land- and fresh-water forms. The action of flood-tide will bring the salt water further up the estuary, rendering the life of more

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marine type than would otherwise be the case, while during ebb-tide the river will cut for itself a deeper channel, leaving dry exposed banks on either side, which during flood-tide will be covered by the combined waters of the sea and the river. In the case of our own Clyde, we find the marine forms abounding even higher up than Port-Glasgow. *Mytilus edulis* exists there by the million, and I have seen over a dozen railway trucks at one time filled with this shell-fish ready for dispatch to other parts of the coast; while cockles, mussels, and whelks are gathered on the Cardross shore, nearly as far up as Dumbarton.

Let us try to reproduce the character of the remains deposited in these recent Clyde beds. When a flood occurs, the river brings down with it trees, branches, leaves, and other debris of the land. During ebb-tides these are swept out, say past Greenock and Gourock, the sand-banks being dry; but on the recurrence of flood-tides they are stranded on the shallow sand-banks, where they soon become silted up, and are so preserved. There, of course, the fresh-water fish and molluscs will leave their remains, and there, also, will lie the more migratory marine forms. Herring, at intervals, visit the upper reaches of the Clyde estuary, and probably are driven even further up the river, being followed by shoals of dog-fish and other carnivorous fish which prey on them. It is not so long ago since a whale was found in the docks at Greenock, while a seal even managed to make its way as far up as Glasgow.

When the fresh water sent down by a river enters the sea, it does not at once unite with the salt water, but, from its lower specific gravity, floats on the top, on the same principle as that on which wood floats; but, there being nothing to confine the area of the fresh water, it flows out over the surface of the salt water in all directions. Thus, when we read that opposite the mouth of the Amazon, and out of sight of land, water fresh enough to drink can be got by simply dipping a bucket in the sea, the natural conclusion is, not that the whole of this part of the ocean is fresh water, but that only a comparatively small depth near the surface is fresh, underlaid by a zone where there is a certain intermixture, while below that is the undiluted salt water of the ocean.

Admitting this to be the case, it will be evident that the waters

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over any such area contain at one and the same time both salt- and fresh-water life forms; and that, for instance, it would be possible for a sea fish and a fresh-water fish, while each remained during life in its own peculiar element, to die about the same time and be entombed together on the sea-bottom.

On the other hand, the sea exerts an aggressive force on the domain of fresh water, forcing its way everywhere with the rise of the tide, lifting the rivers completely off their beds, and causing them to float on its surface. Of course, these remarks on the commingling of the waters are subject to modification, from the fact that fresh and salt water do mix, but we are likely to get a much firmer grasp of the subject if we consider the laws affecting fluids which do not unite, as, for instance, water and naptha.

Some very suggestive instances might be given of the action of the sea in this way. For example, Dr. John Young, F.G.S., has drawn attention to the Loch of Stennis in Orkney, which has been so charmingly described by Hugh Miller.* This loch is about 14 miles in circumference, and its exit to the sea is so narrow as to be crossed by a road-bridge of a single arch. It did not strike me in driving past that the channel was larger than would be required for a stream sufficient to drain the valley occupied by the loch. The opposite shores of the loch have two promontories which approach each other, and are connected by an embankment with several low bridges over which the road is carried, so that it is so far divided as to assume the form of the figure 8, almost becoming two separate lochs. Yet, in spite of its narrow inlet, the *facies* of the lower loch is much more akin to marine than to fresh-water conditions, both in its fauna and flora; these conditions, however, diminishing in intensity the further we are from the outlet to the sea. I observed, in walking across the road dividing the loch, that the channel under each bridge is provided with a sluice which permits the water to flow downwards, but which automatically closes with the rise of the tide, and so prevents the brackish or salt water of the lower loch from flowing inwards, which would make the water of the upper loch useless for domestic or farm purposes.

An even more striking instance of the aggressiveness of the sea is furnished by the Douloch (or Dubh Loch) near Inveraray, the

* "Footprints of the Creator," 1861, page 1.

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following description of which is taken from the "Ordnance Gazetteer of Scotland":—"Douloch or Dubh Loch—a lake in Inveraray parish, Argyllshire, at the foot of Glen Shira, 2 miles N.E. of Inveraray town. An expansion of the Shira rivulet, measuring ¾ mile by 1½ furlong, it lies only 25 feet above the level of Loch Fyne, extends to within 5 furlongs of the Shira's mouth, and in *spring-tides* receives some small portion of Loch Fyne's sea-water. *It yields trout and salmon, sometimes in the same net with herrings and other sea fish;* and takes the name of Douloch, signifying 'the black lake,' from the sombreness and depth of its waters." I have emphasised this quotation by the use of italics.

I visited this loch some years ago, and although the banks of the stream showed by the growth of fucoids that they were regularly visited by the sea, yet there seemed to be no evidences of marine conditions in the loch itself, although possibly some might have been found if there had been more time at our disposal. The facts as stated by observers are very striking, the loch being reached by the sea only at spring-tides, and even then for a very short time; yet not only does the salt water force its way there, but even the sea fish come also. The Douloch could hardly be described as an estuary, yet it is but reasonable to suppose that the remains of marine fishes lie embedded in the mud of its bottom beside those which exclusively inhabit fresh water.

Now, no corresponding phenomena are found in the so-called estuarine beds of the upper coal measures. The evidence is entirely of land or fresh-water conditions, and there is, unless in very exceptional cases, no more evidence of marine conditions than there would be even if the sea had ceased to exist. As we can hardly imagine the existence of a true estuarine bed from which marine organisms were entirely absent, we submit that it would be well to cease naming such beds "estuarine," and simply to call them fresh-water beds.

The case of the Calderwood cementstone, with its accompanying shales, is entirely different. These strata are of true estuarine origin, and contain the remains of land plants and animals, intermingled with those of fresh water and the sea, in a manner which corresponds with the way in which, as has been shown, similar remains are being deposited in estuaries at the present time. That the remains of the land flora were here deposited

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beside those of the denizens of the sea, we have not only the evidence afforded in the late Mr. Coutts's list of fossils, but in that to be deduced from an interesting specimen from the cementstone (fig. 1), showing the frond of a large fern (*Sphenopteris Gersdorfii*), lying beside a marine brachiopod shell (*Productus longispinus*) (fig. 1, A.), and from another specimen from the shale which shews a fern of the same species lying on the same slab with a marine cephalopod shell (*Orthoceras attenuatum*).

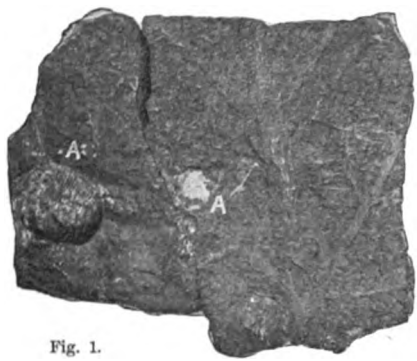

Fig. 1.

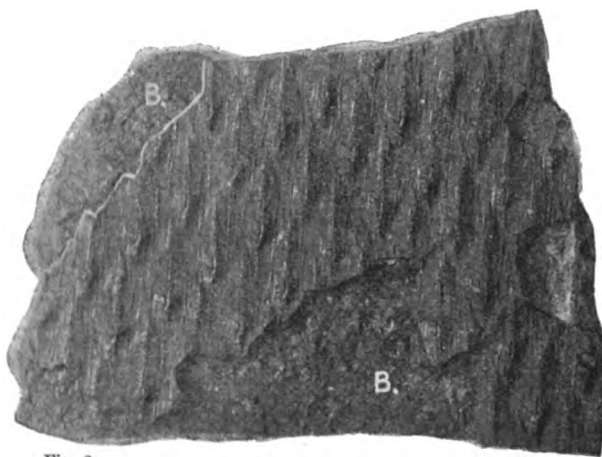

Fig. 2.

Here is an even more interesting specimen from the overlying shale (fig. 2). It is a fragment of a large tree (*Lepidodendron, sp.*), apparently drifted down by the river, the hollowed-out trunk having afforded a home for a colony of small shells (*Posidonomya corrugata*) (fig. 2, B.) which lie closely together. Subsequent pressure has squeezed the tree, flattening it like a pancake, and wherever a division is made up the centre of the specimen, there the shells are to be seen.

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Remains of *Lepidodendron* showing structure are sometimes to be found in these strata, and here are exhibited two very curious winged seeds, resembling the seeds of the plane tree, and supposed to be seeds and cone-bracts of trees of the above genus.

Among the other classes of fossils most characteristic of these beds are large crustaceans, belonging to the genus *Dithyrocaris*, also several shrimps and *Anthrapalæmon*, which appears to have been a fresh-water genus. Of *Dithyrocaris*, three species were previously known before the three new species which have been added from this bed. The fresh light afforded by the latter specimens shows that in the original figure of *D. tricornis* the body and tail segments were wrongly drawn as emerging from the anterior end of the carapace, or, as it might be described, "with its tail coming out of its mouth." *Dithyrocaris* occurs in other beds of marine character, but I am not aware of its being found in any purely fresh-water beds. The genus seems to have flourished here in greater abundance than in any other beds in the West country, and possibly it may have been better adapted to live under estuarine than under true marine conditions. It is worthy of notice, that when the late Dr. Scoular first discovered *Dithyrocaris* at Inkerman, near Paisley, nearly the entire animal was got. These beds were afterwards lost, and during many years since the finding of only one or two carapaces has been recorded. Teeth from several localities (*e.g.*, Orchard) have been, however, not uncommon. In the East Kilbride beds, on the other hand, the carapaces, body segments, and trifid tails have been often met with, but the teeth were very rarely found, and except in one specimen, which I exhibit, and which has apparently a tooth, I am not aware of the existence of any example from these beds which shows teeth in position.

Mr. Coutts's catalogue gives two scorpions of different genera, and it is hardly necessary to repeat that these were land animals. The locality given is Limekilns, where the marine beds also occur, but it is probable that these specimens came from the cement-stone. Another land animal, a millepede, has been described from these beds by Mr. B. N. Peach, of the Scottish Geological Survey.

The mollusca are very well represented, many of the species being however, in a rather dwarfed condition, *e.g.*, *Chonetes*, which

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is here not over one-half the size it attained in the underlying marine bed. *Aviculopecten* shows to advantage, many fine specimens having been obtained. The gasteropods are comparatively rare, but the cephalopods abound to a greater extent than is usual in other beds. This fact I am inclined to attribute to their superior powers of locomotion, which enabled them to take advantage of favourable conditions, and to retreat before adverse ones. One specimen of *Orthoceras*, which was presented by Mr. Paton to the Society's collection, measured, when first seen in the roof of the mine where it was discovered, over 6 feet in length. These molluscs are all of marine habit, and it is to be noted that the fresh-water shells represented by the Anthracomya group are entirely absent.

We come next to consider the fishes, and here there are somewhat different conditions to deal with, as they, unlike the shell-fish generally, could alter their position upwards and downwards just as the water suited them. In accordance with this, there are associated together in these beds the remains of fishes which are generally confined to different and distinct beds, such as ganoids, fresh-water sharks, and marine sharks. The ganoids are represented by seven genera, viz., *Elonichthys*, *Eurynotus*, *Gyrolepis*, *Megalichthys*, *Rhizodus*, *Amphicentrum*, and *Cœlacanthus*, all highly characteristic of fresh-water beds, but almost never found under marine conditions. For instance, *Megalichthys*, the most numerous as well as the most widely distributed of all our fossil fishes, abounds from the calciferous beds to the very top of the Carboniferous system, yet always in fresh-water beds. The fresh-water sharks are represented by *Gyracanthus* and *Diplodus*, and the same remarks apply also to them. The marine sharks are largely represented, but it may be more convenient to defer their consideration till we come to another head of the subject.

Some very interesting questions may well be asked here. How comes it that the remains of fresh-water and marine fishes are both got in these beds? Did the ganoids only come down when a a flood on the river, or a strong wind from the shore, made the water sufficiently fresh to suit their habits, and did the sea fishes only come up when these conditions were reversed? Or else was the water deep enough and was the river large enough to provide

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over this area a layer of sea water and a layer of fresh water, each of sufficient depth to allow large fishes to select water suitable for their own particular habits? Or, again, did these fishes jointly inhabit a tract where the waters of the river and of the sea had mixed sufficiently to be not too salt for the inhabitants of fresh water, nor yet too fresh for those of the sea? In this latter event it would almost necessarily follow that the different classes of carnivorous fishes would meet, and it would be interesting to know whether the large ganoid swallowed the little shark, or the large shark devoured the little ganoid, or what would be the probable result of an encounter between two large specimens of their respective orders.

Such questions, while very suggestive in themselves, are much more easily asked than answered; yet some light on the last one might possibly be got by examining the coprolites, although even if fish remains were found in them, the difficulty would be to identify the fish from which they were dropped. The fact that very large fishes existed in these waters is shown, not only by the remains of the fish themselves, but also by the size of the coprolites, one recorded by Mr. Coutts weighing no less than 1¼ lbs.

The only other bed of which we know, that shows anything approaching this mixture of fresh- and salt-water forms, is a bone-bed, about one-inch thick, at Abden, ¼ of a mile east of Kinghorn, in Fife, described by Mr. William Anderson in a paper read before the Edinburgh Geological Society.* Its principal difference from the beds under review appears to be that in the Abden bed the fish remains seem to have been drifted, and a list accompanying the paper shows a very slight resemblance to a list of those from the Kilbride beds. Mr. Anderson's paper is followed by one by Dr. Traquair, entitled "Remarks on the Fossils of the Bone Bed at Abden,"† and in it he mentions the East Kilbride beds, making some very interesting remarks on the different classes of fishes which frequented the clear seas and the estuaries of the Carboniferous era.

It may also be mentioned that this Abden bed occurs at the very bottom of the lower limestone series, close on the volcanic rocks which mark the close of the calciferous series, and thus, lying

* *Trans. Edin. Geol. Soc.*, vol. v., page 310.

† *Ib.*, page 314.

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at a lower level than the Calderwood series, it is much more on a level with the strata at Thornton Hall.

I trust I have shown, in the course of the foregoing remarks, that these so-called estuaries were in reality great fresh-water lakes.

The questions are sometimes asked—Can we tell by the fossil contents to what part of the marine series any particular bed belongs? Have changes been going on during the period of the deposition of these beds, either by the introduction of new species or the dying out of old ones, so that the position of any particular bed can be identified by the variation in its fossil contents from those of any other bed? These are important questions regarding which there is still room for investigation. So far as I am aware, any changes (and no doubt there were such) were very slight, and at least not sufficient to cause well-marked life-zones, such as distinguish many of the other formations. We are therefore unable to tell by such a test even whether any particular bed belongs to the lower or the upper limestones of the group.

It is true that there are several beds which can be distinguished by their fossils; but it is rather by the grouping of the various forms than by the fact that certain of them are confined to these beds. A notable example is the bed over the Hosie limestone at Thornton, which, lying in a quite unexpected position, was identified by its fossil contents.* One entomostracan species *(Polycope Youngiana)* seems to be confined entirely to this bed, but that only goes to confirm the identification which was made from its general list of fossils, before this particular species was discovered in it.

Nor does there appear to have been any progression or development in the several species themselves during the long period represented by the marine beds of the Carboniferous formation, even those few specimens found in the marine bed discovered by the late Mr. Skipsey, 66 fathoms above the ell coal,† showing no such signs, so that we are forced to the conclusion that the close of the upper limestones left the species very much as they had been at the beginning of the lower limestone period. It is true that there

* *Transactions*, vol. iv., page 282.
† *Ib.*, vol. ii., pages 52 and 144.

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are considerable differences in the appearance of examples of the same species from different localities, but I submit that this is not due to differences of period but of locality; the conditions afforded by one habitat rendering it, as compared with the conditions afforded by another, more or less favourable to their growth or development. It should be remembered that our Scottish strata do not possess the intensely marine characteristics of the English and Irish limestone series, as they were laid down much nearer land, and were therefore more subject to influences which affected not only the beds themselves but also their contained fossils.

If we follow up any particular species—say, for instance, *Chonetes Laguessiana*, which is a common shell both in the lower and upper limestones—we find the above remarks exemplified. This species, fairly large in the shale below the main limestone at Thornton, and small in the shale overlying the Hosie limestone in the same locality, seems to have attained its largest size in the shale overlying the Calderwood limestone, while in the cementstone shales immediately above it dwindles to one half the size. And so with varying fortunes we trace it through the several beds, till at Gare, almost at the top of the upper limestones, it is nearly as large as in the Calderwood limestone shale, while at Orchard and Arden, about the same horizon, it is comparatively small.

If further proof on this point were required, we might refer to the "Catalogue of the Carboniferous Fossils of the West of Scotland,"* where we find the Calderwood beds referred to the *upper* limestone series, although that conclusion is now generally considered at fault, and it is believed that the beds really belong to the *lower* limestone series. I am not aware what evidence the authors had in support of their statement, but I suspect that it was probably the resemblance of the limestone shale to that of Gare, and also the fact that cementstone is found in the upper limestones, which led them to this conclusion; but it is plain that had there been any distinct progression or alteration in the fauna, these distinguished palæontologists would have detected it, and consequently would have placed the strata in their proper position. It may, however, be remarked in passing, that the evidence on which the Calderwood beds are now placed in the lower limestone, though strong, is not absolute, and it would be rather

* See page 61, *antea*.

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interesting if Messrs. Young and Armstrong's first surmise should still prove to be correct.

Having now considered the proofs of estuarine conditions afforded by the presence of certain fossils in the strata under notice, let us next take up that arising from the absence of other fossils as bearing upon the same question. It will be clear that sedentary forms exclusively inhabiting purely marine or fresh-water localities are not to be expected here, and so we find it to be in fact. Unfortunately there are comparatively few fresh-water forms found in the Carboniferous formation to which we can refer, almost the only ones being those of the entomostraca, and the anthracomyan group of shells—both of which are absent in the Calderwood beds. With regard to purely marine fossils, it will be observed from Mr. Coutts's list that the crinoidea, ostracoda, and polyzoa are entirely absent, that corals are only represented by a single species, *Zaphrentis Enniskilleni*, and that from a single locality, while foraminifera are rare.

What conclusion can we draw from the absence of ostracoda, as they are about the most cosmopolitan of all organisms, no water being too fresh, too salt, too pure or too impure? I confess that I am entirely at fault here, and I shall be glad of any suggestions which will help to unfold the mystery. The other absent orders are those which so largely predominate in the underlying limestone shale, and which are, above all other forms, held to show its highly marine character. I submit that their absence goes to prove that the cementstone series was not deposited in the clear pure waters of the open sea.

Let us now consider the conditions under which the cementstone was laid down. Its fauna and flora resemble those of the shales which under- and over-lie it. At the present time "Portland cement" is manufactured by burning a mixture of chalk and mud from the estuary of the Thames, and we can easily imagine a similar mixture being formed under natural conditions somewhere in the mouth of that estuary. It is very probable that to conditions such as these the Calderwood cementstone is due.

Again, these shales must have been formed under tranquil water—so tranquil that there is considerable difficulty in imagining conditions under which it could have been secured. The only theory I can advance is, that they may have been deposited in a

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hollow or basin, deep enough to be beyond the ordinary reach of the waves and possibly defended by a high protective bank or bar from the action of the open sea. One evidence of such tranquility is afforded by the ferns, which have been laid down without a single frondlet out of place. In further proof of the quietude under which the organisms in this bed were deposited, I exhibit a specimen of *Archæocidaris Urei*, an urchin differing from our ordinary echinoidea, in that its plates were not soldered together into a nearly solid mass, but, that, as pointed out by Dr. John Young, F.G.S., they overlapped each other and were loosely held together, so that the whole test was probably flexible. At all events, although this is a common organism, and though many thousands of specimens have been seen by members of the Society, yet, with the exception of one in the Hunterian Museum, that exhibited is the only one known, so far as I am aware, which shows the plates and spines in position. Unfortunately, the slab has been broken off across the test, and rather less than half of the entire organism, with its long slender spines, has been preserved (fig. 3).

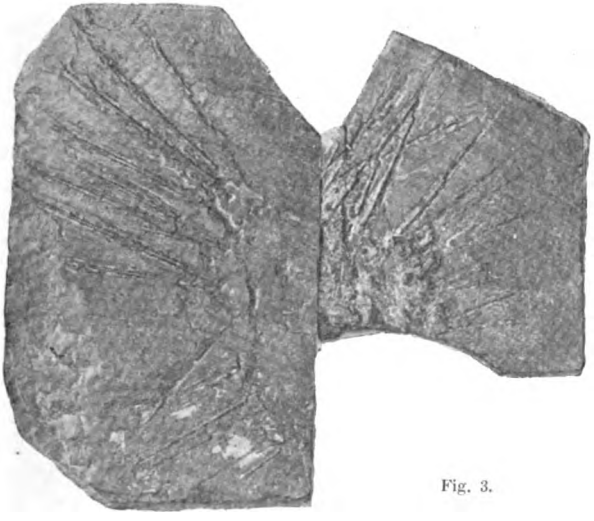

Fig. 3.

Even more remarkable is the state of preservation of the cartilaginous fishes, which are generally represented, even in beds laid down under very tranquil conditions, by single teeth

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or detached spines. I do not think that the case is overstated when I say that these beds have yielded a greater number of finely-preserved specimens of marine sharks than all our other Carboniferous beds put together. From this locality we have that remarkable specimen of *Psephodus magnus* exhibited and described and figured before the Society in 1883,* which shows, belonging to one head, teeth which had previously been attributed to no less than four different species of fishes.

Here also was found that beautiful specimen of *Cladodus* (now in the author's collection) which has proved to be such a puzzle to palæontologists. Dr. Traquair named it *Cladodus Neilsoni*, and some years ago described it before this Society,† and has since read a paper to the Royal Physical Society of Edinburgh in which he devotes about two pages to it.‡ It is also referred to in Smith Woodward's "Catalogue of Fossil Fishes in the British Museum." In this specimen the head is intact, with the lower jaws attached, and the teeth in both jaws are in position, although like the teeth of modern sharks they were not in sockets but were movable. The arches of the gills, portions of two fins, and several bones forming a chain are preserved. It is plain that all these fragments would have been dispersed by the slightest commotion, and that the water must have been perfectly still when the fish lay on the bottom, and until, indeed, it was covered by the muddy deposit in which it now lies.

I now exhibit from this locality a specimen of *Psammodus porosus*, showing three teeth in position, and which is unique so far as I know. When first seen it is said that there were four teeth lying in their proper places.

Another remarkable specimen from Calderside belongs to the Petalodus order of sharks, and the teeth very much resemble those figured by Smith Woodward § under the name of *Janassa*. This fish appears to have been lying in its natural position, the jaws in the specimen being horizontal, and by a most fortunate circumstance the fracture which laid it open passed right through the mouth, so that the upper jaw is now seen on one slab and the

* *Transactions*, vol. vii., p. 392.

† Unfortunately the description has not yet been published.

‡ *Proceedings Roy. Phys. Soc. Edin.*, vol. ix., part 3.

§ "Catalogue of Fossil Fishes, British Museum."

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lower jaw on another. There are over a score of teeth, and they appear in their natural position. This specimen was presented by its owner to the Museum of Science and Art in Edinburgh, and Dr. Traquair informs me that it belongs to an undescribed species.*

In all the above specimens large portions of the cartilaginous endo-skeleton have been preserved, a most unusual circumstance, as any part of these skeletons has previously been very rarely found, and then generally in a very undefined form.

The ganoid remains from this bed are also very fine, some of the smaller Palæonicidæ being entire, while there are extremely good examples of (so-called) *Gyrolepis*.

One other point yet remains to be stated. I cannot but think that this bed was deposited in much less time than that which is generally allowed for such an accumulation, and that to such a quick deposition is due the fine preservation of many of the fossils. The ferns may have been coated with fine mud even before they reached the bottom, and the sharks may have been completely encased before the putrefaction of their flesh set in, as otherwise the cartilaginous skeletons would have been scattered and the cartilage itself destroyed, disappearing like the fleshy parts of the animal, as is the case with specimens of similar species in other strata.

In conclusion it may be mentioned that I have not sought to follow these beds out of the East Kilbride district, except to mention the neighbouring localities of Newfield, Dykehead, and Boghead, in connection with the marine shale lying between the limestones. There is also an overlying shale at these localities which contains many fine fossils of marine types, but it must be left to others to say if it is the extension of the beds found under the cementstone in East Kilbride, and if so, whether it gradually loses the estuarine character it possesses in that locality to assume a marine one in the others. If it can be shewn that it does so, there may also be a possibility of assigning the direction of the currents, and even the course of the river itself.

Meantime I trust that this communication will be considered of sufficient interest to justify me in having taken up so much of your time.

* *Janassa Wysei*, as it has since been named, was the subject of a paper by Dr. Traquair, read before our Society, in 1894, which will appear in a future part of the *Transactions*.

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No. IX.—On the Occurrence of Tachylyte at Loch Screden, Mull. By Professor M. Forster-Heddle, F.R.S.E., &c. With an Illustration (Plate III.) and Two Diagrams.

[Read 11th May, 1893.]

Tachylyte is the black, bottle-glass selvage which is occasionally seen upon the contact surfaces of basaltic dykes.

In a paper upon the tachylytes of the Western Islands of Scotland, published in the *Quarterly Journal of the Geological Society* for April, 1883, by Professors Judd and Cole, these authors give what is termed a detailed "History of previous opinions on the subject."

In this, after showing that a variety of terms had been applied to this selvage upon the Continent, they say "Zirkel and others describe different varieties of basalt-glass under the name of tachylite, and by the same designation the Scottish examples were referred to by one of us in 1875."

Under a second heading, "Distribution and mode of occurrence," due credit is given to Dr. M'Culloch as having been the original discoverer of two, out of what are termed the "five known localities."

Under the above headings no notice is, however, taken of the observation, and very full, interesting, and accurate description, of the occurrence of this substance by Prof. Archibald Geikie at Ben Tigh in Eigg,—published in his admirable paper on the geology of Eigg in the *Quarterly Journal of the Geological Society* in 1871; nor of a chronicle of the occurrence of the same substance at the Quiraing in Skye, as submitted to the Mineralogical Society in 1880 by the present writer, and published in the *Mineralogical Magazine*.

In this latter paper the writer showed, by analysis of both, that the composition of the tachylyte, and that of the dolerite to which the vitrified skin or selvage was attached, were nearly identical; and that the former was thus probably the suddenly-chilled portion of the flow: and he also showed—by a contrasted analysis of the pitchstone of Arran—that while tachylyte is the glassy condition of a *basic* rock, pitchstone stands in the same relation to an *acidic* rock.

In a note which was appended to their paper by Professor Judd and Mr. Cole, subsequent to its reading, they credit M. Necker

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$\frac{1}{1}$

FLUIDITY OF TACHYLYTE SELVAGE.

$\frac{12}{1}$

SECTION OF STELLAR BASALT.

M. F. H. del.

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with the primal recognition of the above;—"the true nature and properties of the material are very clearly defined;"—and they credit the present writer who was the analyst of both with having only brought Necker forward to receive the above award. What Necker actually did was only to affirm that the so-called "gallinace" of Beal was not pitchstone. He did not recognise it as being tachylyte, which he does not even mention in this connection at all, though he notices it in his "Regne Mineral" of 1835,—placing it, as an aluminate of lime, beside obsidian and sphærulite.

As Messrs. Judd and Cole have come to the same conclusion as that previously announced by the present writer—a conclusion which indeed was inevitable after the still earlier analysis by Delesse—I have the less hesitation in passing certain other of their conclusions under review, in connection with the recording of the occurrence of tachylyte sheathing a dyke at a new locality, and that in quantity altogether enormous in comparison with that seen at *all* the other Scotch localities combined.

The locality referred to is the northern angle of the entrance to Loch Screden in Mull.

While examining this part of the coast of the island, from Mr. Harvie Brown's yacht, we were attracted by the appearance of basaltic pillars, and landed at the point near Derag Skier. We here found a development of basaltic structure more diversified in its features than that seen at the not far-distant Staffa, though by no means so picturesque.

A pavement more regular in its columns than that of the Giant's Causeway, and a wonderfully fine circle or wheel, with a depressed circular axis or throat, are two of the features most deserving of being recorded. This last, though only properly seen from an overhanging cliff, very much surpasses the well-known "rock" of the Rock and Spindle near St. Andrews. The pillars greatly exceed those of the latter in dimensions, they are much more regularly disposed, and at their peripheral extremities are suddenly incurved upwards—simulating somewhat the expanded petals of a camelia.

The dyke, the sides of which are sheathed in tachylyte, occurs immediately to the east of this pillared basalt, cutting some of the smaller groups both vertically and horizontally. It forms the southern limit, as it were, of a vast grass-clad slope of debris, of about 1000 feet in height, which faces the western ocean, and

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which has very infelicitously been called "the Wilderness." From a concentric coronet of cliffs which crowns this slope, the dyke may be seen cutting the sward in an almost vertical sweep of 800 or 900 feet. When it reaches to within about 50 feet of the water it suddenly bends to the east, and becomes nearly horizontal in part of its course, but with a slight dip to the south-east. In the higher parts of its course it cuts bedded dolerites, melaphyres, and amygdaloids; the denser columnar basalt seems to have deflected it at the point where it meets that bed, but, at a short distance southward of this, it cuts the basalt diagonally.

As the writer did not ascend the turf-clad slope to any height, he cannot speak positively, but, so far as he could see, the tachylyte appeared only where the dyke cut basalt. The basalt of the dyke is much denser and finer in grain than that of the pillars; it is of a light grey-brown tint, that of the pillars being dark brown. It contains no druses with zeolites; in this differing from the basalt of the pillars.

The tachylyte coats both sides of the dyke, and the exposure is in all respects perfect. The pillars have been swept clean off the upper surface of the horizontal bend for a distance back from the sea-cliff of 20 or more yards; so that the upper skin of tachylyte is walked upon, and a surface, much broken-in upon it is true, but of several hundred square yards, of black-bottle-like glass, is exposed. This upper skin or selvage is thin, being from a quarter to half an inch in thickness, and the transition into the ordinary structure of the rock is, upon this surface, somewhat sudden. On the lower selvage, again, the tachylyte is from 2 to 3 inches in thickness, and the passage into basalt is very gradual.

The dyke, where cutting the basalt, has an average width of 9 feet. High up on the slope it seems to assume greater dimensions. At one spot the dyke is divided by a portion of the pillared basalt, here nearly amorphous; this crosses it diagonally, and hitches it slightly upward to the east—like a reversed fault.

The westernmost portion of the dyke thins off, so as to underlie for a short distance this apparently-included mass of basalt. The thickness of the selvage of tachylyte increases as the mass thins; and when the dyke is about 8 inches wide it appears at first sight to be all black tachylyte.

The marginal portions are all jet-black glass, so smooth in

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fracture as to reflect perfectly. These margins have such eminent conchoidal fractures as to present the appearance of an agglomeration of small black bullets or egg-shaped masses. It gradually becomes pitchy in lustre, and brown in colour, towards the centre. The most perfect glass has a specific gravity of 2·728.

This portion of the tachylyte passes in a vein-like process for about 15 yards through the columnar basalt. Its average thickness is 6 to 7 inches, but it thins to 2 inches; there it is clear lustrous glass throughout, much fractured; while a short distance to the east it expands to a thickness of 22 inches. Here it is still tachylyte throughout, with a columnar structure like that of starch. The little columns are about 2 inches long by $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness. They are for the most part in a nearly vertical position—that is lying across the dyke—but are grouped in fasciculitic clusters. This patch of the tachylyte bears in miniature a very striking resemblance to the truncated western extremity of the Scuir of Eigg where seen at the point of Bridianach.

In that portion of its course where this vein-like process has a thickness of less than 7 inches, its rents cause it to assume the form of balls or ovoidal masses, which are flattened on the sides by mutual contact. These balls may be extracted entire, their general length coinciding with the width of the vein. Hammer-fracture of these balls discloses a structure somewhat approaching that of banded hornstone—the brilliant velvet-black of the tachylyte passing through bands of brownish colour with a duller and more vitreous or pitchy centre.

It has been stated above that the dyke cuts the pillars somewhat diagonally: the pillars, however, have *not* been rent diagonally, but at right angles to their vertical position. The rent thus passes through the colonnade of pillars step-ways—the glassy plug of tachylyte filling up what would otherwise be angular vacuities in a similar step-like manner. So comes it that the selvage of tachylyte at one side of a rent pillar may be little more than a fourth of an inch in thickness, while at the other it may be 3 or 4 inches. This is best seen in the easternmost portion of the dyke.

From the angles of these pools of tachylyte, small branching veins of the substance penetrate the basalt, thinning off to nothing.

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This proves the fluent condition of the tachylyte to have been perfect. But the once-perfect fluidity of, not only the tachylyte, but of the basalt itself, is made manifest by the structure of the balls or ovoidal masses above referred to,—as disclosed by the microscope. Sectioning shows the rock of the pillars to be one of minute crystal grain. The lath-shaped labradorite is in crystal groups of a somewhat stellar arrangement. The augite, in larger crystals of nearly uniform dimensions, is pale-green and granular or structureless. The olivines are clear. There is little or no glass. Sections of the central portion of the dyke show it to be a dolerite of fine crystal grain, in which labradorite in lath-shaped crystals is the most clearly defined ingredient; the augite is in unusually-lengthened crystals, in fact its crystals are almost as lath-shaped as those of the felspar; it is much fissured, and of a reddish-yellow tint; there is some calcite, and but little of either glass or magnetite.

Where the basalt of the dyke has narrowed down to 7 inches or less in width, its structure and its appearance are entirely altered. This alteration is progressive through three stages. In the first of these it has assumed the colour and much of the lustre of cobbler's wax, but the lens shows the colour to be unequal in intensity, and that this inequality is due to darker bands which consist of belts of contiguous, or for the most part contiguous, spheres; these have a stellar or internally-radiating structure. As the divergent rays penetrate to different extents into the magma, the term *stellar* would define this variety of basalt fully better than *spherulitic*. At the same time it has to be noted that, where these darker subcrystalline groups occur so frequently or closely as to impinge upon each other, the usual straight lines of arrested growth appear. The sections of these concretionary arrangements do not disclose a definite crystalline radiation, but one like what would be assumed by a multiplicity of tapering feathers,—as of those from the neck of a cock—tied into a ball, and viewed in section: a feather of darker tint showing broad and flat at one point and tapering to nothing at others where presented edgeways. This greater darkness along certain lines and in certain spots may be due either, wholly or partly, to difference of material, or only to difference of position. There is no definiteness of crystalline form to guide; and the polariscope merely deepens

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the general tint, and upon revolution displays the dark cross without any alteration of tint at any part. The only other structure disclosed is an occasional concentric banding near the centres of the groups. To say that the darker feather or blade is probably mainly augite, and that the paler is mainly labradorite, is to introduce unwarranted guessing.*

Another stage in the alteration of structure is to be seen where, in a narrower part of the vein, the darker material predominates, while the lighter has, by comparison at least, paled in colour. Here the latter has definitely segregated apart either in distinct spherulites, or in spherulites which have played the part of nuclei to the growth of the forementioned feathered structure. These spherules, which have by a powerful transmitted light a fawn colour, have a well-developed radiating acicular growth in their peripheral portions, but their more central substance shows a confused acicular arrangement of spicules very similar to the willow-leaf structure displayed in sun-spots. Some portions of the slides show these spicules to be definite, acicular, lath-shaped crystals, free from any yellow stain, and shining up clear and colourless. They obscure at about the same angle as does labradorite. These spherules are surrounded by a clearer and somewhat yellower zone, which looks like glass, but does not act on light as such. Through this clearer zone the divergent radiations of the central spherule pass to enter into the general dark substance, which here consists of a congeries of rayed spherules which come into mutual flattening contact with one another throughout.

The third and complete stage of departure from the structure normal to basalt is that of the tachylyte itself. This is a compact, umber-brown, perfectly isotropic, glass; but it carries numbers of paler spheres with radiating acicular structure, which brilliantly display the cross, with also a concomitant darkening and paling of alternating crystalline rays, upon revolution of the beam of light.

In all three stages of this structure, perlitic fracture is abundant and open; and throughout it all, indifferently in position, minute spheres of chalcedony giving the dark cross are occasionally seen. Rarely these have a centre of quartz, and frequently they are surrounded by a pale zone. They do not act as centres to the diverging clusters of acicular crystallisations.

* See the lower figure in Plate III.

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The rich brown of the tachylyte glass and of the rock throughout certainly so far encourages the belief that the opacity is due to separated magnetite.

It has in the foregoing remarks been stated that at the date at which the author made his analysis of the tachylyte of the Quiraing, he conceived it to be that portion of the lava-flow which had been solidified by coming into contact with the cold surfaces of pre-existent rock. This actual solidification *in situ* as glass seems, both before and since, to have been invariably the accepted explanation of its occurance.

Geikie * writes—"In many examples the fineness of grain of the outer band culminates in a perfect volcanic glass. The glass doubtless represents the original condition of the rock of the dyke. It was suddenly chilled and solidified by contact with the walls of the fissure."

Professor Bonney writes—"The name of tachylyte has been applied to varieties where the material remains in the form of glass."

Professor Judd says †—"These dolerites in turn passing into basalts which when suddenly cooled assume the form of tachylyte or basalt glass. The differences between gabbro and tachylyte on the one hand, and between granite and obsidian upon the other, are not to be accounted for by a difference in geologic age, but are a consequence of the different conditions under which the rocks have solidified;" and further on—"in situations where very rapid cooling has evidently taken place, basalt-glass has been formed."

Mr. W. Muir considers that where the glass occurred the dykes could not have run for long.

Professors A. Geikie and Bonney, it will be seen in the above, and in the context of the quotations, put it that the glass when suddenly cooled has remained in its original condition; and when slowly cooled has assumed the more and more coarsely crystalline conditions of basalt, dolerite, and gabbro. Judd, again, puts it that basalt *assumes* the form of glass. There can, however, be little doubt that in the latter case the apparent difference of view is due to a less happy precision of expression. All, however, seem to consider that there has been *immediate contact-solidification*.

* *Transactions Royal Society Edin.*, vol. xxxv., pt. 1, page 35.

† *Quarterly Journal Geological Society*, vol. xlii., page 50.

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*One of the above-mentioned balls of the Loch Screden dyke unmistakably disproves this.**

Its section shows a selvage of blue-black tachylyte about a fourth part of an inch in thickness. The central portions of the ball are made up of stellar concretions of basalt; towards the sides these are arranged in bands which consist of a series of these stellar spheres disposed in a single line or layer, looking in section like the links of a chain. From one of the selvages of tachylyte there projects downwards and then forwards, *i.e.*, in the direction of the flow in the rent, a process or tongue of the tachylyte, some inches in length. This process has the peculiar hooked form of the Bill of Portland. The bands of stellar arrangement are folded over this process, in conformity with its outline; and, in the bay or circular recess formed by its hooked extremity, there is clearly delineated the whirls of an eddy of the still liquid basalt (Plate III.). The tachylyte has here manifestly been dragged forward, *in a condition of plasticity, if not of fluidity*, while the flow of the more central portions was still continuing.

Two of the conclusions of Professor Judd's paper, which I desire to pass under review, are these. First, that crystals may be dissolved by their magma *under a relief of pressure*;—and second, that the cavernous condition of many porphyritically-disposed crystals results from their having been attacked and dissolved by the glass or magma which envelopes them. From the first of these I entirely dissent. The second, I think, is to be accepted in *not* the greatest number of cases, and is a subject which calls for special research.

Professor Judd enunciates the first of the above in the following words:—"The facts described point to the conclusion that crystals formed under great pressure in the midst of a fused magma may, on the relief of that pressure, be attacked and dissolved by the magma in which they were originally developed." Now this is not only exceedingly repugnant to all chemical teaching, but it is in direct antagonism to all experimental experience. The compositions and decompositions, solutions and resolutions, in Nature's laboratory, so far as we know of them, are elaborated in precise conformity with all the laws which guide us in the operations

* This ball is now deposited in "the Scottish Collection of Minerals" in the Edinburgh Museum of Science and Art.

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of our laboratories: and it is our invariable practice, in bringing about solutions and decompositions of substances which offer unusual resistance to ordinary reagents, to seal them up in tubes of glass or iron, and subject them to increased pressure and to high temperatures. But here it is propounded that these crystals were attacked when the pressure is relieved, and the heat is departing! The above inference or contention is all the more extraordinary from the fact that Professor Judd in his paper on the "Older Peridotites of Scotland," over and over again insists upon *increase* of pressure augmenting solvent power; he speaks of it as "a well-known physical law"; and refers to the researches of Daubree, Sorby, Guthrie and others, as "placing the fact beyond all doubt!" He also makes it one of the postulates of his "Theory of schillerisation."

With regard to crystals being attacked and dissolved by the glass or magma in which they lie ("have been caught up" is so far theory), I should not be prepared to offer so emphatic a dissent, though it is to be remarked that a caveat was entered, both by Mr. Teale and by Mr. Bauermann, as to this when Professor Judd's paper was read.

The "solution" of a crystal of definite composition by a molten magma of less definite composition in a rock, cannot be regarded as an example of ordinary physical or adhesion-solution, but as a chemical decomposition. And so the object aimed at, so to speak, is the formation of a new compound in the magma. And this compound would be possessed of a definite form which would disclose itself certainly to the polariscope, and even probably to the microscope. Now, inasmuch as certain of these so-called dissolved crystals are surrounded on all their margins (whether they show flat crystalline faces, or re-entering hollowed out bays), by a fibrous crystalline fringe, which radiates from these surfaces, it may be held that this fringe did not consist of any portion or ingredient of the magma, crystallising round the large crystal as a nucleus, but consisted of a substance formed by the union of the magma, or a certain portion thereof, with the dissolved outer layer of the crystal.

But where does such a contention land us, except in this—that as this fringe is a proof of attack and new formation, there can have been no attack—*i.e.*, "solution"—if the new formation is

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not made manifest: and in far the greater number of cases *no* such crystalline fringe and *no* alteration in polarisation-appearances is visible in proximity to the margin of so-called "dissolved crystals." It is certainly to be regretted that those who advocate solution of these crystals had not submitted analysis of the glass and magma, so as to demonstrate that its composition conferred upon it the solvent power claimed, and had not at the same time submitted some tangible proof of its alteration after it had exerted the solvent power claimed.

The most common of all the appearances of these "dissolved crystals" is, however, perfectly inexplicable to the writer, under the known laws of either physical or chemical solution. All who make rock-sections their study must be familiar in these "dissolved crystals" with the deep and sinuous channels which inosculate in their *terra firma*, and the deeply indenting bays with narrow entrances, which sectioning *in three directions* shows to exist.

Now, in the cases both of physical and chemical solution, the nearer the action approaches to saturation the slower is the action, and the less is dissolved. But here it must be the opposite. The bulk of the liquid is free to act upon the outside, and currents would there carry away the solution so formed, and allow the access of another quantity of the solvent; but not so with the portion embayed. It is evident that solution is going on much more speedily here: both the deep penetration and the widening out within the entrance vouch for a far greater amount of removal of the solid. More is removed and faster. A new supply of solvent must be reduced to a minimum—diffusion alone can bring it in, as there can be no currents. With the quantity embayed—as with Hamlet's mother—"increase of appetite must have grown by what it fed on." (See fig. 1.)

Fig. 1.

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It would certainly seem to be a more probable view that some portion of the glass was simply caught up during the crystal formation.

The whole subject is obscure and calls for special research, and that in connection with what are called "negative crystals," for the one subject must bear upon the other. This name,—"negative crystals,"—is a most unfortunate one, for it is at the same time both misleading and inadmissable. It is applied to certain hollows or spaces in the body or mass of otherwise-solid crystals, which spaces, it is held, were originally vacuous, or filled with vapour or liquid, and have probably been subsequently filled more or less completely with certain products of decomposition—said products having, according as it suits theory, either been force-pumped through the solid substance of the crystal from without; or certain constituents have been force-pumped out of the substance of the crystal, by a process of selective decomposition unknown to chemists, but perfectly simple and altogether above the necessity of explanation to theoretic geologists.

In the term "negative crystals" negative is an adjective, and crystal is a substantive. The adjective qualifies the substantive. But a crystal is more than a substantive, it is a substance: and it is a substance with so definite a composition and so regular an arrangement of its parts as to possess a regular geometric form, which with flat faces and salient angles incloses that substance; which has definite lines of cleavage, a definite action on light, varying in different directions, and a hardness which varies also in different directions. *No one of which properties of crystals do these so-called "crystals" possess!*

Moreover, in the sense in which it is proposed to use the adjective here, its opposite "positive" has never been applied. But while that has not been *so* applied, the *whole term* has for long, and that for the purpose of defining certain properties of crystals of the highest importance in the science of optics, and in mineralogy. In *this* application the term "holds the field," so that its application in any other sense is inadmissable. The things intended to be defined are hollows in the crystal, with boundaries which, in accordance with the crystallographic arrangement of the molecules, have flat sides *accordant with external faces of the crystal-form of the substance itself.* It has been attempted

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to be made out that the hollows were formed by some mysterious agent (not condescended on) of the force-pump process; but every one engaged in the formation of regular crystalline forms is familiar with the difficulty of making, even in circumstances of no undue pressure, artificial crystals which do not contain such hollows generally holding some of the mother-liquid with all its alien solutions.

If these hollows be plugged with any solid substance, as that substance must have taken a cast of the crystal sides, it is *an endomorph;* and as in all probability an isomorphous substance would not take such a cast, but would crystallographically associate itself in or with the including crystal-substance, the plugging substance must be *a pseudomorph.* Those who desiderate correct names might be satisfied with *pseud-endomorph*, which tells that they are not imbedded crystals: the word is shorter than "negative crystals," apart from the argument that the latter term is in all respects objectionable.

In stating above that during the artificial formation of crystals in the laboratory, there frequently occur in them vacuities of definite form with flat sides, which bear an evident relation to the crystalline form of the salt itself, there has come before us one of the objections, so far as recognised knowledge or experiment permits us to speak, to the theory that similar vacuities have been formed in nature in any *less* simple manner (as by any agent acting from without).

Every agent which produces change of form or alteration of structure in a physical existence, or alteration of chemical arrangement, or decomposition—which is the loosening of pre-existent arrangement and combination in a chemical compound—must act *along the lines of weakness present in all crystalline structures.*

Our present tabulation of these lines of weakness or "Structure Planes," as they are termed, is (as shewn in figure 2 on the next page):—

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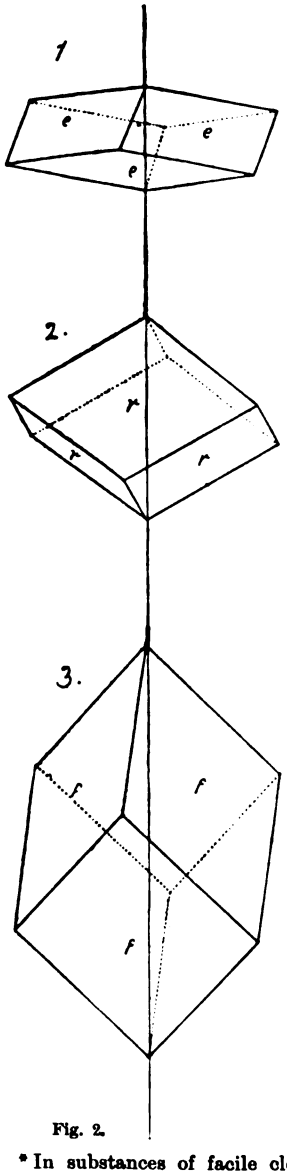

Fig. 2.

1st. *The direction of molecular instability*, or "gliding plane"; along which direct pressure permits of a sliding of the molecules over one another, and by the polar revolution of one or more layers of molecules produces twin laminæ of excessive tenuity.

2nd. *The direction of cohesive weakness*, or "cleavage plane"; along which the crystal rends when a disruptive force is applied at certain sides and in certain directions.

3rd. *The direction of chemical weakness*, or "solution plane"; along which water or other solvent acts in preference to, and with greater rapidity than along others.

And our present knowledge of these goes only so far as to show that they lie in different directions* —the first truncating the terminal edges of the form delinated by the second; and the second truncating the terminal edges of the form delinated by the third. These directions of weakness give rise to the faces in calcite, *e*, *r*, and *f*, whose relation to each other in position is shown in the figure. This being so, great difficulty lies in conceiving how any agent of solution could force its way into a crystal to *abstract* portions thereof *locally*, and in a series of spots,—so forming the vacuities,— without at the same time

* In substances of facile cleavage,—as baryte—water holding dust in suspension occasionally is by capillarity drawn into the cleavages, and so simulates a solution plane.

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disclosing the path of its entrance by a similar action; and still more, without, in accordance with the ordinary and recognised law of action of solvents, operating along the plane of chemical weakness.

Now, in an admirable paper* Professor Judd himself shows that "felspar" of an olivine gabbro, at Coruisk, contains those enclosures lying not in *one* but in *five* different directions. These directions he states to be parallel to the two pinacoid faces, the two prismatic faces, and to the basal face; all of which faces, be it observed, are usually-occurring crystal-faces of the species. It certainly then would seem to be the most direct conjecture that these pseud-endomorphs *were deposited upon its faces during the growth of the crystal.*

Professor Judd, however, takes an entirely different view. The occurrence of vacuities of various forms upon the faces of crystals during their growth is established both by observation and experiment: of the structure-planes of crystals, the first has been established by experiment; the second by experiment; and the third by observation, if not also by experiment. But these established facts do not suffice to bear out Professor Judd's view, for he writes,—"I have long felt that it is impossible to account for the characteristics presented by the minerals of deep-seated rock-masses without assuming the truth of the above postulates." The "above postulates," four in number, are the basis of his "Theory of schillerisation." For this the recognised structure laws *do not suffice*, and of his adopted postulates three are hypothetical, though certain somewhat obscure facts are adduced which are held to support them.

Professor Judd writes,† "although the planes of cleavage, of gliding, and of susceptibility to chemical action in a crystal are all *distinct from one another*, yet in most, if not in all crystals there appear to be certain curious and very interesting relations between them." Further on we find that these "relations seem to indicate the mutual interchangeability of the cleavage planes and the gliding planes. That a remarkable relation also exists between the third set of structure-planes—the solution-planes—and the gliding-planes, seems to me to be indicated by

* *Quart. Jour. Geol. Soc.*, vol. xli., page 412.

† *Mineralogical Magazine*, vol. vii., page 82.

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my study of some of the rock-forming minerals in deep-seated masses." But what of *distinctness* from one another does this bear, or evidence? A "relation" which amounts to "mutual interchangeability" hardly leaves enough of "distinctness" to be of use to science!

But more indefiniteness of position follows, for we find, first, that twin-planes "become" planes of solubility; second, that pressure developes a second and then a third solution-plane; third, that sometimes one sometimes another of these is the "easiest"—easier even than the normal solution-plane; and lastly, that such planes "arise parallel to the directions along which strain is directed." Thus they may lie in *every* direction! All this is little else than the shuffling of certainty into uncertainty.

But any residual definiteness of known or discoverable position of the solution-plane is altogether done away with in considering the chemical processes by means of which these "eaten-out" hollows are regarded as having been filled; for Professor Judd writes—"It is probable that under the enormous pressures which exist at great depths in the earth's crust, *the whole substance* of such crystals is permeated by fluid and gaseous material, capable of exercising a chemical action on the materials through which they pass"; in so passing these fluids are supposed to dissolve out ferric oxide, sometimes depositing it in the "negative crystals" of the mineral which yielded it, but sometimes carrying it off and "depositing it in those of labradorite."

It is not only inexplicable to chemistry, but open to chemical doubt that a solvent should, *without interfering with the composition of a crystal in other respects*, be able to extract protoxide of iron and precipitate it as peroxide *in shut cavities*. What of the silica which was in combination with the iron protoxide; would its precipitation as a residue in the crystal not render the latter altogether opaque?

On the other hand, it is a fact, familiar to all chemists, that substances alien to the composition of a crystallising body should be *extruded from its molecules*, and be deposited in layers, or sprinkled upon its faces during its growth. This fact is equally familiar to mineralogists, being specially well seen in the "capping" of quartz, of calcite, and indeed of many crystals. If not the explanation which meets all cases, this at least is not one which jumbles up the known with the merely speculative.

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That water and probably more powerful solvents permeate *rocks* is clearly shown by the formation of agates, and by the deposition of saponite, calcite, and other decomposition-products between, or among, the component crystals of a rock; but that such solvents pass between the opposed contact-surfaces of the component crystals of the rock,—dissolving thin layers from off the said surfaces,—is surely more probable than that they burrowed to the interiors and left the surfaces unaffected. It has been maintained that many of the so-called examples of schillerisation are in truth instances of the effects of mere ordinary weathering—a somewhat bronzy lustre and darker colour being produced by surface-peroxidation of the protoxide of iron of the unaltered mineral.

Three of the best cases of schillerisation known in Scotland I have by analysis determined to be due to this chemical alteration. These are—the diallage of the Cuchullin Hills in Skye; the so-called "bronzite" of Balhammie Hill in Ayrshire; and the schiller-spar of Belhelvie in Aberdeenshire.

The diallage of Cuchullin, which is, when fresh, dark green and of moderately high lustre, has on its outer surface a thin skin of a brown tint, and a lustre approaching to that of paulite,—for which mineral it was for long taken. When sections of the two portions are examined, they are found to exhibit no difference in structure; but there has been peroxidation in the crust.

The blocks of the "bronzite" of Balhammie, when broken up, display the lustrous crystals of paler and paler *green* tint the further they are removed from the surface. Analysis shows these crystals to be serpentine-pseudomorphs after enstatite; there being peroxide of iron in the superficial crystals, but none in the deep-seated ones.

The schiller-spar of the Black Dog Rock, and of the Belhelvie Hills, is the only true enstatite schiller-spar in Scotland. At the Black Dog Rock, where the outer layer is always subject to sand-friction, the mineral is grass green; while the exposed crystals seen at the quarries on the west side of the Belhelvie range appear as bronzy buttons. The same is seen in the pseudo-enstatite crystals which stud serpentine at many other localities, there being no structural alteration in any.

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No. X.—Notes on an Excursion to Glen Fruin, with a Description of the Moraine on its South Side. By John Renwick. With Two Illustrations.

[Read 11th May, 1893.]

The second excursion of this season was taken on 29th April to Helensburgh and Glen Fruin. Going up the new Luss Road the party first visited a cutting on the West Highland Railway, in course of construction between Craigendoran and Fort-William, and which is expected to be ready for traffic next year. It will open up a considerable part of the country now almost inaccessible, and bring Lochaber so near us that we may be able to spend a Saturday to Monday at Ben Nevis, or the Parallel Roads of Glen Roy, or even examine the Glen Spean moraine on a one-day excursion.*

According to the Geological Survey the rocks through which this cutting passes belong to the lower division of the calciferous sandstone series. They consist of red and white sandstones, with bands of cornstones, and, where exposed, a little to the east of this particular point, dip to the south-east at an angle of 20°. As seen in this particular exposure, they are chiefly sandstones of a reddish colour, or of a mottled red and white, suggesting that the staining material had percolated through them from above. Within 150 yards to the east of the Luss Road there are, at least, three faults exposed where the rock-faces are beautifully polished and striated by the friction attendant upon the movements. In one case the line of motion is at an angle of about 15°, in another it is almost horizontal, in a direction N. 15° W., and S. 15° E., magnetic. A photograph of one of the finest slickensided faces was taken by Mr. Sinclair, and is now exhibited (see page 97). In another part of the cutting is a bed of peculiar limestone with flinty layers.

The following description of the section here was given in the *Ardrossan Herald*, by Mr. John Smith, shortly after the excursion:—"The first bit we examine is a red and white sandstone with occasional highly calcareous patches and curious globular hollows bristling with calcite crystals. A little further to the east of this point the rocks in the cutting are in several parts highly slickensided, the sandstones on the slickensided faces having taken

* This has since become an accomplished fact by the opening of the West Highland Railway on 7th August, 1894, and the members have already had some pleasant excursions to various localities on the route.

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a polish and glitter as smooth as glass, and look as if they had been striated in closely set lines with a diamond, the striæ being also highly polished. These slickensided parts are just the divisional

planes of faults or shearing, and, at places where the sides have slightly parted, infiltration of calcite, &c., has taken place, the lime having not only taken a cast, but the glitter of the slickensided walls between which it has been introduced. In another part of the cutting there is a bed of that peculiarly-banded limestone which has been deposited as a precipitate from water. In this instance there are layers of flinty and cherty matter intercalated with the limestone."

Returning to the road, which we follow as it ascends the hill behind Helensburgh, we reach the summit at a height of about 330

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feet, and soon get a glimpse of the lower part of Lochlomond with its tree-clad islands, while the Conic Hill on its eastern side, which we are to visit in July, rises conspicuously in the background. We are now in Glen Fruin, and can see to the north-east the farmhouse of Inverlauren, and distinguish the Scots Pine which stands behind it on the moraine (first pointed out by Mr. Dugald Bell, F.G.S.). We can also follow the line of the moraine itself as it stretches up Shantron Hill to a height of from 600 to 700 feet above sea-level.

Just before us, to the south-west of Inverlauren, Glen Fruin changes its direction. Above this point it runs from N.W. to S.E., or more accurately, N.W. by N. to S.E. by S., but here it turns and trends almost due east, till the low alluvial land on the side of Lochlomond is reached, where it curves round to the north-east. After crossing a small stream flowing north-west into the Fruin, we come to a grassy ridge on the north side of the road, pointing N. 10° W., magnetic, or straight up the glen, the top being about 290 feet above sea-level. This ridge is continued, on the opposite side of the road, through the moor, where the ground has not been disturbed by cultivation. At the point where it is cut by the old road it rises 30 feet above the little burn just mentioned, and here the 300-feet contour line is reached. In many places the ridge has been considerably excavated for sand and gravel, and at one spot where material is being taken for building purposes in Helensburgh, a good section has been exposed. A photograph of this section, by Mr. William Sinclair, is now exhibited. It shows stratified sand and gravel with a layer of peat at the top. In the heaps of material rejected by the workmen are boulders of various sizes, of quartz, schist, &c., most of them being smoothed and rounded (see the next page).

The ridge begins to curve round slightly more to the east as it approaches the wood which runs alongside of Bennachra Moor, but as soon as we cross the dyke we find that it turns abruptly and runs almost due east in a sloping direction up the hill. Very distinct at this point, it is obscured in several places by the growth of the moss on its sides, or by being cut through by streamlets. At a height of about 400 feet one of these burns has formed a miniature glen, in which the fresh green of the "birks" contrasts pleasantly with the dull moor, whose monotony seems only accentuated by the sparse, silky tufts of cottongrass and the

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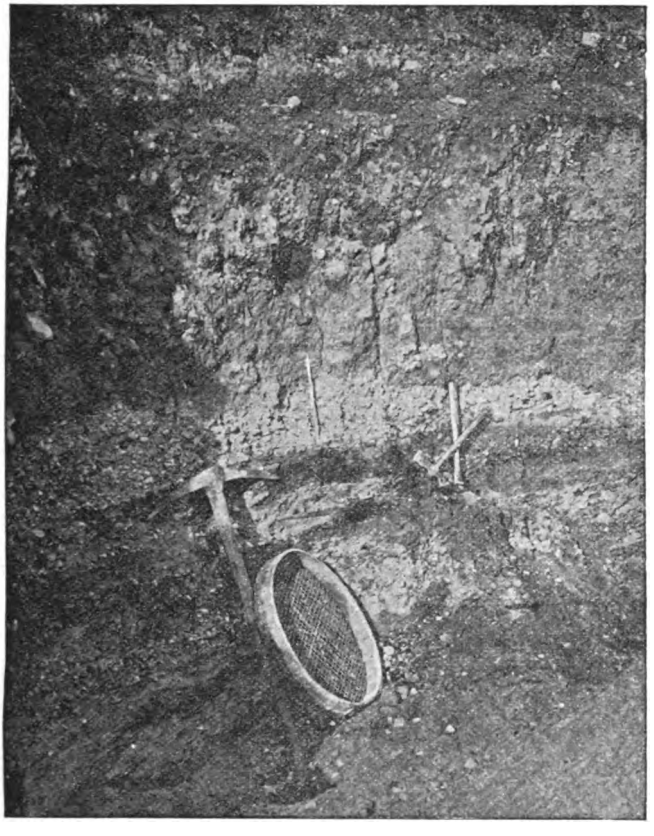
sweet-scented, tender shoots of bog-myrtle, barely discernible at this period of the year among the withered heather.

From this and other points the line of the moraine on the opposite, or northern, side of the valley is quite visible.



As some of the party wanted to leave by the 6.50 p.m. train, we did not go any further along the hillside, but returned to Helensburgh by the old Luss road. On the descent to the town we saw on the roadside, at a height of about 200 feet above sea-level, one of those boulders of granite, with large flesh-coloured crystals of felspar, frequently met with in this district, and even as far as the north of Ayrshire, and whose native place seems to be between Glen Falloch and Glen Fyne, according to the evidence

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adduced by Mr. Bell. If I remember correctly, I have seen a large number of similar boulders in Glen Kinglas.

Beyond the birch-fringed burn the ridge continues gradually to ascend the hillside in an easterly direction. At about 450 feet above sea-level it is less distinct, but soon becomes more prominent again. At about 540 feet there lies on it a boulder of fine-grained grey schist measuring 9 feet by 5½ by 3. A small streamlet cuts it at about 600 feet, a little farther on it seems to die out, apparently at nearly the same height as the corresponding ridge on the opposite side of the valley, the distance between the terminal points being about two miles as the crow flies. It should be stated that the heights here given were calculated by the aneroid, and are therefore simply approximations.

This ridge is not quite so well marked as the one on the north side of the glen, brought to our notice by Mr. Bell, but, I think, there can be as little doubt about the morainic character of the one as of the other, each being simply the complement of the other, and the whole representing a moraine formed by a glacier coming down Lochlomond and pressing up into Glen Fruin. That the ice travelled in this direction seems pretty clearly indicated by the shape of the ridge, or series of mounds if it be argued that it is not perfectly continuous, which is that of a segment of a circle or wide-mouthed U, stretched across Glen Fruin, *with its opening to Lochlomond.*

The greatest break in the continuity of the moraine is between the termination of the portion on the northern side of the Fruin and the grassy ridge, already mentioned, on the southern side of the same water. The former passes to the west of Inverlauren farmhouse and continues a short distance towards the river, but as the field is cultivated the slight surface curve of the ridge is not easily distinguished. The grassy ridge on the south side near the river is also under cultivation, but still remains very distinct. Where it is crossed by the farm road the upper portion is seen to be composed of sand with a slight admixture of gravel. On the north-western side of the road it reaches its lowest level and ends in a steep slope 50 to 60 feet above the burn, which has down to this point washed its western base, and which has here worn a channel down to the underlying sandstone. On the north-east it slopes steeply to a little haugh on the side of the Fruin, which has evidently cut into the ridge at a former period.

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The distance between the terminal points, where the central part of the ridge is not continuous, is not greater, I think, than about 300 yards, and may be found to be even less when the slight ridge on the Inverlauren side is carefully traced. The break in the continuity of the moraine is easily accounted for by the loose material of which the ridge is composed having been washed away by the long-continued action of the river.

The existence of stratification in the gravel on Helensburgh moor seems, at first sight, inconsistent with the supposition that this material is part of a moraine, but it may be explained by the circumstance that the glacier did not reach the summit of the watershed between Glen Fruin and the Clyde valley. The water from the higher ground being therefore "ponded" back, the loose material laid down in it would assume the stratified form we see, and the overflow would escape by the burn to the south which falls into the Clyde at Craigendoran. The col at its source is a few feet under the 300-feet contour lines, and thus coincides with the height of the gravel. As the glacier retreated the detritus would be laid down nearer Lochlomond, which would account for the mounds that exist lower down the valley.

The objection has been raised that it is unlikely the Lochlomond ice would turn aside and spread up Glen Fruin, when it could have passed down the Vale of Leven or up Strath Endrick and Strath Blane. But passing up the Endrick and Blane valleys would be turning much farther aside than moving up Glen Fruin, and the col at the head of the Blane valley by which the ice would escape is over 300 feet above sea-level, actually a little higher than the point in Glen Fruin at which the glacier ended. The Conic Hill, 1175 feet high, Inch Cailliach, 200 feet, and Inch Murren, 200 feet, form a ridge, which, although both islands were over-ridden, would tend to direct the ice away from the Endrick valley, and towards Glen Fruin the lowest part of which is in a straight line with the open channel above these islands. In saying this I do not argue that the ice did not pass up the Endrick valley, but only that it is quite as likely, if not even more likely, that it went up Glen Fruin.

It will not be denied that the ice widened after emerging from the neck at Ben Lomond. There the depth of the loch varies, from 570 feet between Stuckgown and Rob Roy's Prison, below

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Tarbet, to 400 feet at Rudha Mhor (the great point). The width at its narrowest is half a mile, and the 400-feet contour lines are about a mile apart.

The lower portion of the loch is several miles wide, while the depth nowhere exceeds 70 feet, generally much less, and the ice here must of necessity have spread out considerably. In moving into Strath Endrick or the Vale of Leven, or both, there would be considerable obstruction to its free passage. The Vale of Leven is very much narrower than the lower part of Lochlomond, and even not much wider than the upper part at the 400-feet contour lines, which are only 1⅛ mile separate below Bonhill.

But it is probable that the ice did not get a perfectly free exit from the Vale of Leven into the valley of the Clyde. The Loch Eck branch of the Loch Fyne ice, coalescing with that from Loch Long, would fill the upper reaches of the Firth, and force the latter up by Dumbarton, and this even although it was not then in such great thickness as at an earlier period.

In view of all these circumstances it seems to me quite reasonable to suppose that the Lochlomond ice would spread up Glen Fruin, and that if it did so, and terminated before passing over the col dividing that valley from the firth of Clyde between Helensburgh and Greenock, the shape of the resultant moraine would be just what we find it really is.

Further, I think it likely that the supply of ice to Glen Fruin would cease before the supply to Lochlomond. The latter has an extensive elevated feeding-ground containing a great many hills of 2000 feet and upwards, quite half-a-dozen rising to over 3000 feet, while the former has less feeding-ground of any height, only four summits on its northern border rising to 2000 feet. No doubt at the period of greatest extension the ice from Loch Long and from Loch Goil overflowed into the Gareloch and into Glen Fruin, but we must bear in mind that this moraine was formed after the ice had passed its maximum and had diminished considerably. The Gareloch has no feeding ground of its own sufficient to produce a glacier, and must have received its ice from Loch Long, the col between the two, which is just opposite the mouth of Loch Goil, and about 260 feet elevation, showing the rocks all around to be beautifully grooved and striated.

To reach Glen Fruin the ice would require to rise to at least

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667 feet, the height of the col between the Glen and Garelochhead, and travel uphill 2½ miles from the present shore of the loch. Not only so, but as the ice had to pass the head of the Gareloch this valley would require to be filled to a height of nearly 700 feet ere any ice from Loch Long could get into Glen Fruin; indeed, to form a glacier sufficient to stretch fully five miles down the glen to Inverlauren, and rise 500 feet above the bottom of the glen, a very considerable thickness of ice would have to pass over the col. But if the ice rose 720 feet above the present sea-level the whole of the peninsula of Rosneath would be covered, and the extra accommodation thus provided by the wider area would take off the pressure on the pass to Glen Fruin.

On the whole question I would again submit the view that it is much more likely this moraine has been formed by ice from Loch-lomond than by ice coming down Glen Fruin.

In conclusion, I may say a word or two about the discovery of the moraine on the south side of the glen. The first time I visited the ridge on the north side was, I think, in October, 1891, when Mr. Bell conducted Mr. William Jolly and myself over it. We went on to Glen Finlas, where we saw a fine ravine, 40 to 50 feet deep and 12 to 15 broad, worn through the sandstone just below its junction with the metamorphic rock. The different way in which the erosion of running water affects the schistose and sandstone rocks is well illustrated here. Above the junction the valley, although steep, is open by comparison with the cañon below.

On that occasion neither Mr. Jolly nor myself was satisfied with the theory that the moraine had been formed by a glacier coming down Glen Fruin, and the more I looked at it the less likely did the theory seem. It appeared to me that if such had been the case the ridge would have run in quite the opposite direction from its actual one down the glen as it descends the hillside, whereas it actually trends away from the foot of the valley as it falls in height.

I was unable to attend the excursion to the moraine in May last year, but while living for a short time at Helensburgh last September, and taking an occasional holiday, I re-visited the locality with Mr. Jolly with the intention of tracing the possible continuation of the moraine round the shoulder of the hill into Glen Finlas, but a heavy rain-storm stopped us, and sent us back in a

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"drookit" condition. On our way up we had a look at the "kame" on Helensburgh moor, and noted a mound to the east as worthy of future examination. Returning a day or two later to the "kame" and following it across the moor, I was delighted to find it turn beyond this mound and run up the hillside to about 600 feet above sea-level, as just described. I was, of course, desirous of getting the opinion of other members of the Society on various points, but until the excursion, with a sketch of which I began this paper, no opportunity occurred, with perhaps the exception that a few days after my discovery of the southern ridge, Mr. Sinclair visited the Inverlauren portion with me, and took the photographs from which two of the illustrations to Mr. Bell's paper on it* were taken, when in the slanting light of the September afternoon, the shadow cast by the ridge was sufficiently strong to mark its course along the face of the hill.

The Glen Fruin moraine in its extension on both sides of the valley is worthy of note by all students of physical or glacial geology, and further discussion of the various questions which have been touched upon may clear up some of the points still obscure. A visit to the locality may be recommended as one full of pleasure, provided the moor and the day be dry. The scenery from the upper parts of the ridge is unsurpassed, with Lochlomond and its islands to the east, the Highland hills to the north, and Glen Fruin at our feet. Bennachra Moor is the property of Mr. Lumsden of Arden, who kindly gave the members of our Society permission to visit it on any convenient occasion.

Transactions, vol. ix., page 345, plate XIII.

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No. XI.—On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch.—II. Clava and other Northern Localities.

By Dugald Bell, F.G.S. With a Map and Section.

[Read 25th May, 1893.]

In previous papers we considered, first, the "high-level shelly drifts" in North Wales and certain parts of Ireland, at from 1200 to 1400 feet above the sea, and argued, from several points of view, that these could not be received (though frequently offered) as proofs of a "great submergence" in Glacial times. We next referred to the "shelly-clay" reported to have been found at Chapelhall, near Airdrie, some forty years ago, and which, since then, has been commonly adduced as proving submergence in Scotland to the extent of at least 510 feet. We set forth, as clearly as we could, a number of reasons which seemed to have weight, singly and collectively, against this clay being accepted as a genuine "shell-bed," deposited by the sea in the position indicated.* Some other instances now remain to be noticed, particularly that at Clava, on the river Nairn, about seven miles from Inverness, which has been called "the one clear and decisive instance of a high-level Arctic shell-bed in Scotland."† Along with it we may consider (if time permits) some patches of shelly-clay and gravel found at a lower elevation along the eastern coast of Aberdeenshire, which have also been frequently adduced as furnishing confirmatory evidence of submergence.

I. Clava.

This instance was first described by Mr. James Fraser, C.E., of Inverness, about ten years ago.‡ The following is a summary of his observations:—The shells occur in an old clay-pit at the base of a broad terrace about 70 feet in height, the upper of two long gravel ridges which at this point run parallel with the river Nairn, on the eastern side of the valley. The top of the terrace is about 570 feet above sea-level, and the shelly-clay, as nearly as may be, 500 feet. The section consists, in descending order, of—

1. Soil and gravelly subsoil, - - - 4 or 5 feet.
2. Yellowish Boulder-clay, - - - 45 „
3. Fine sand, - - - - - - 20 „
4. Blue shelly-clay (bottom not reached), - 7½ „

* *Transactions*, vol. ix., pp. 100 and 321. † Dr. Crosskey (in note to author).

‡ *Transactions Inverness Scientific Society*, vol. ii.; *Transactions Edinburgh Geological Society*, vol. iv.

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beneath which, the succession of Boulder-clay, Old Red Sandstone, and Lower Silurian gneiss was reasonably inferred.

The upper yellowish Boulder-clay (2) consists of "gravel, sand and stones, mixed with a small proportion of clay, and containing fragments of Old Red Sandstone and of gneiss and its allies, in nearly equal proportion." It gradually passes downward into (3) "a bed of fine yellow sand about 20 feet in depth, and showing marks of stratification." This stratum of sand had not been found at any other part of the terrace. "In every other spot, on the same level, the terrace seems to consist of Boulder-clay."

Below this sand is found the shelly deposit (4), "consisting of a stiff blue clay, or silt," sharply defined from the sand above it, and containing "a slight proportion of small stones, mostly well-rounded and water-worn, and all—unless with very few exceptions—consisting of gneiss rock." Mr. Fraser had "not been able to find the same bed at any other point, nor to ascertain what it rests upon." The shells were most numerous at a depth of about 2 feet from the surface of the clay, and none were found among the sand or Boulder-clay overlying it. Careful search was also made "in the Boulder-clay in the immediate neighbourhood for fragments of shells, but without success."

The shells taken from the clay were examined by Mr. Jamieson of Ellon, and by Mr. David Robertson, Millport, and the following among others were identified, all common to the glacial beds of Scotland:—*Littorina littorea*, *L. rudis*, *Mytilus edulis*, *Leda pernula*, *Natica Grœnlandica*, *Tellina Balthica*, *Astarte compressa*, *Buccinum undatum*, *Trophon clathratus*. The prevailing shells were the *Littorina*, but fragments of *Mytilus* were also very common.

Now, the question meets us—Is this bed of clay, part of an old sea-shore or sea-bottom, laid down by the sea where we now find it, and therefore proving a submergence of at least 500 feet?

During the summer of 1891 we spent some days in the neighbourhood in the hope of obtaining some light on this point, and will now give the result of our own observations.

The Overlying Deposits.—The upper part of the valley of the Nairn contains a very striking series of glacial mounds, extending on both sides of the river. As we descend the valley, the moraine matter becomes in general more spread out into long ridges and terraces parallel with the valley, these being also as a rule more

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gravelly in composition than the upper mounds. At Clava these ridges occur chiefly on the eastern side of the river, and two of them are very well marked—first a lower ridge, consisting mostly of coarse gravel, with large stones perched here and there upon it; and then this higher ridge or terrace in which the shelly-clay occurs. This terrace is, to all appearance, simply a great bed or bank of Boulder-clay—sand, gravel, large and small stones, of near and more distant kinds, confusedly mixed together, and bearing, many of them, the unmistakable marks of the ice. This deposit extends for some distance back from the centre of the valley, and gradually merges into other and still higher ridges or trains of débris sweeping along the base of the neighbouring hills. There is nothing here to suggest the action of the sea; everything indicates the operation of land-ice.

Nor does the underlying bed of *sand* furnish any evidence of the presence of the sea. It seems simply one of those "intercalated beds" of partly-stratified materials, which, in the "total absence of marine organisms," are viewed as having been produced "by the action of water escaping from the melting ice-sheet," and affording "no evidence in favour of marine submergence."*

The Shelly-clay.—We come, then, to the underlying bed or sheet of *shelly-clay*. Notwithstanding the difficulty of gaining access to it, owing to the amount of débris that has slipped from the bank above, we saw enough (with an hour's assistance from a neighbouring cotter and his shovel) to satisfy us of the accuracy of the section as given by Mr. Fraser. The only question is, is this shelly-clay *in place*, or as left by the sea?

Difficulties.—At this point we may remark that all the difficulties which we enumerated in a former paper with regard to the deposit at Chapelhall (*all*, excepting the limited and imperfect evidence) seem to apply to this case at Clava, and some with even greater force. As at Chapelhall, there is the want of continuity in the bed; it seems to be a mere strip, or patch, embedded in the glacial deposits;† and though apparently more extensive than that of Chapelhall, it is not of that common occurrence in the district, which we should expect, if it really marked an old sea-bottom. Then, as we remarked with regard to Chapelhall, if the sea once

* Dr. J. Geikie, "Great Ice Age," 2nd ed., pp. 245-247.

† See Supplementary Note, page 118.

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stood here, 500 feet higher than it does now, it is strange that there should be no traces of it at innumerable lower levels, marking the steps by which it first rose and then receded, occupying in both movements, undoubtedly, a long period of time, and giving a double chance, so to speak, to its impress and relics being left all over the country. It is especially strange that no traces of a former sea-level, at anything like this height, should be found in the many side-glens branching off from the main valley, where such traces would most likely be preserved. This remark applies very forcibly to the neighbourhood of Clava, for during such a submergence, Loch Ness would be a great arm of the sea, and the numerous side-glens would then be far-reaching, sheltered bays and inlets diverging from it. Yet nothing, in any part of these, has been found to corroborate this alleged submergence—nothing but this strip, or sheet, of shelly-clay, in a not very sheltered position, near Clava.

Further, it is strange, if all the surrounding region under 500 feet was at one time the bed of the sea, that the "subsequent glaciation" (which is the agent usually put forward) should have removed all evidence of it, except this under notice; and yet that the upper Boulder-clay, the product of the "post-submergence glaciation," should contain no trace of marine remains! This, the advocates of the submergence admit to be a difficulty which they cannot explain.* They credit the ice with far more wonderful achievements than ordinary glacialists do; for they suppose that it has removed—"cleared out" or "swept away"—all the marine remains (except one or two limited patches) from miles upon miles of former sea-bottom, and that it has "made away with them" so effectually that no trace of them is now to be found in its deposits! What did it do with them, not in one locality only, but all over the country? It is sometimes said to have "carried them out to sea." But in almost every locality, there were in the track of the ice-sheet scores of impediments to such "clean sweeping," and of *traps*, so to speak, which would have caught and retained a fair part of the spoil. Or it is said to have "destroyed" them; but we know very well that ice does not, as a rule, destroy such marine remains; that they are, in fact, very indestructible, and in some form or other—in recognisable

* "Great Ice Age," 2nd ed., p. 390.

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fragments, however minute, and often in well-preserved specimens—they are found all over the world, wherever ice can be shown to have passed over a former sea-bed in its progress.

These are general, obvious, *primâ facie* difficulties, which we do not see how it is possible to explain away, and which apply, not to one district only, but to every part of the country.

General Remarks.—We may add here the general remark, that in an area like Britain—especially North Britain—largely mountainous and interpenetrated with arms of the sea,—it is evident that when glacial conditions prevailed, the ice must frequently have traversed former beds of the sea; and when it did so, the probabilities are all in favour of marine remains—sometimes detached shells, sometimes masses of shelly-clay—having been taken up by it, and left elsewhere in its progress over the neighbouring land. The known instances of this are already so numerous, that I need not again mention them in detail.* They seem naturally to suggest the inquiry, whether the same cause which produced such effects elsewhere, did not also produce them here,—especially as the operation of any other cause that has been suggested seems to be attended with great, and indeed insuperable, difficulties.

The Ice-transport Theory.—Passing on now to consider the more positive evidence in favour of these shells at Clava having been transported by an ice-sheet, we note, in the first place, that there is every evidence of that agent having been in operation in great force in this very neighbourhood. The whole district is one of intense glaciation, and the evidences of it meet us at every turn—in huge perched blocks, rounded knolls, polished and furrowed surfaces of rock, great heaps and trains of morainic debris;—in no part of Scotland are all these features more conspicuous and remarkable than in this upper valley of the Nairn.

Direction of the Ice.—And from all these features, it most clearly appears that the motion of the ice in this region, during great part at least of the glacial period, was from S.W. to N.E.—or W.S.W. to E.N E.—issuing from the mouth of the Great Glen, and gradually curving round more and more to the east, till, on by Nairn and Forres, the direction was nearly due W. to E.†

* *Transactions*, vol. ix., p. 342.

† See Sir A. Geikie's Map of the Glaciation of Scotland; and the Map of the district in the Inverness Scientific Society's *Transactions*, vol. ii.

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We might give a number of particulars of the transport of boulders showing this direction—easily distinguishable varieties of granite; Old Red conglomerate with pebbles of reddish quartzite; gneiss from the Stratherrick and Monadhliath mountains—all carried from S.W. to N.E., "or parallel to the trend of the coast of the Moray Firth at this point." But we content ourselves with referring to parts of the Fifth and Sixth Reports of the Boulder Committee of the Royal Society of Edinburgh. "Whatever the transporting agent may have been," remarks one of the writers (Mr. Jolly), "that these rocks were carried from their native sources, and scattered widely and numerously to the eastwards, cannot for a moment be doubted."*

Another point is, the evidence found all over the district, not only of the ice having turned eastward, but of its *rising* in its progress—being pressed *upwards* over higher ground than parts which it had already traversed. Of course, to no floating ice could this apply; and it is clearly proved by many of the boulders having been carried from lower to higher levels. Thus, to give a few examples, Mr. Fraser states that "on Craig-a-Clachan, above Dunlichity Church, a hill itself consisting of gneiss, there are numerous pieces of dark brown sandstone flags carried up from the Loch Duntelchaig basin, and also bits of a great dyke of red porphyry on the south side of that loch scattered from the base up to 1190 feet."† And Mr. Jolly, in the Fifth Report of the Boulder Committee, already referred to, states that blocks of the Stratherrick granite, which occupies nearly the centre of the strath, are scattered on the very top of the neighbouring ridge of conglomerate, at between 1400 and 1500 feet. But we need not multiply instances — the whole region is remarkable for its conspicuous perched blocks; and it is evident from the configuration of the country, that the ice, in being forced to turn eastwards, would also be forced *upwards* to some extent in its progress.

This is in itself an interesting fact, and should be kept distinctly in mind, as an important element in the solution of this problem we have now in hand.

Cause of this Direction.—A question which the observers for the Boulder Committee seem not to have dealt with is: *Why* was the

* Fifth Report of the Boulder Committee, 1879, p. 75.

† *Trans. Edin. Geol. Soc.*, vol. iv.

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ice "forced" to move eastward, and in some degree upward, in this fashion? What could compel the great body of ice issuing at the northern end of Loch Ness from the Great Glen to take this direction, with the wide Moray Firth opening out into the North Sea straight before it?

The answer undoubtedly is—Neither the Moray Firth nor the the North Sea *was* open before it.

The ice-blocked condition of the North Sea, which the late Dr. Croll demonstrated in one of his most interesting papers,* must be kept clearly in view.

The ice from Easter Ross and the North of Scotland generally, as Messrs. Peach and Horne have shown,† was compelled to curve round to the N.W. and pass over Caithness, instead of passing straight out to the North Sea. Similarly, Mr. Jamieson has shown that the ice from the seaward side of the Kincardine and Forfarshire mountains was compelled from the same cause to turn northward, hugging the east coast of Aberdeenshire.‡

Here, in this district, there were so many powerful glaciers coming in from the west,—from Glen Morrison, Glen Urquhart, Glen Farrar, and the neighbourhood of Ben Wyvis,—that there must have been an enormous pressure of the ice towards the east. In these circumstances,—egress by the upper part of the Moray Firth being effectually barred and closed, and new accessions pouring in by all these glens and passes to the west,—the only possible course for the ice was to the east, along the base of the Monadhliath mountains, and over the Red Sandstone plateau towards Nairn and Forres. (See Map on next page.)

Its Extent.—In our necessarily rapid survey of the district, we found it extremely interesting to mark how *far back* from the present opening of the Firth this easterly trend of the ice began. It becomes exceedingly pronounced about 10 or 12 miles south of Inverness, on the eastern side of Loch Ness, say opposite Glen Urquhart, where it is evident a large body of ice must have come in. We have no doubt it can be traced still further south. Its evidences are very distinct near Loch Duntelchaig, and the other smaller lochs which abound in that neighbourhood, whose very

* "Climate and Time," chapter xxvii.

† *Proceedings Royal Physical Society of Edinburgh*, vol. vi.

‡ *Quarterly Journal Geological Society*, vol. xxxviii.

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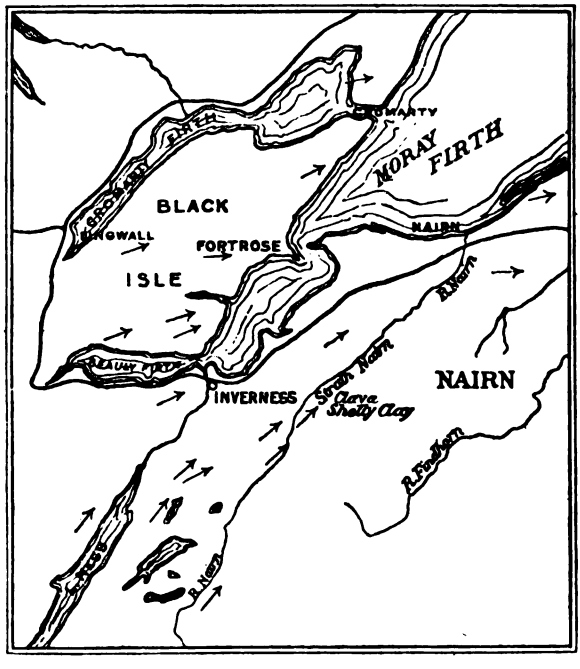
form and direction seem to afford an indication of the course of the ice. Dunchea, a bold hill of conglomerate at the head of Loch Duntelchaig, with a steep precipitous side facing eastwards—a big *roche moutonnée* in fact—has at its base great ridges of moraine matter extending past it in a N.E. direction. The fact that the ice began to deviate eastwards so far back from the opening of the Moray Firth is an impressive indication of how completely blocked the Firth at that time must have been. It



could not be otherwise. The Beauly Firth, joining it at nearly a right angle, was the outlet to a great body of ice from the mountainous region to the west; while, farther north, an immense sheet of ice from the Ben Wyvis district stretched right across the Black Isle into, and at one time, it would seem, even across the Firth itself.

Nothing can be more certain than that such was the course of the ice in this district. And the *reason why* it was so becomes, when we look at it, perfectly clear.

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Did it pass over part of the Sea-bed? The next question that arises is, Did the ice pass over any part of the sea-bed in its path towards Clava? We think it very evident that it must have done so. Even if the relative level of land and sea was unchanged during the whole glacial period—which we do not maintain—there may quite well have been a time (perhaps before the Great Glen ice came forward in force) when the ice from the Beauly Firth and Ben Wyvis side extended across the Moray Firth, and abutted at some height on its southern shore. We are not sure that we need give up this supposition in favour of any other. At the same time we do not argue for the relative level of land and sea being quite unchanged during the glacial period. On the contrary, we admit a certain degree of submergence,—a moderate degree, to the extent probably of 100 feet or thereby. But we must distinguish things that differ; a submergence of 100 or 120 feet is a very different thing from one of 500 or 600 feet. And we hold that the smaller submergence, as regards this country, is more in accordance with what is known of submergence elsewhere during the glacial period, and with any intelligible theory of how it was brought about;* and it also seems sufficient to account for all the clearly-ascertained phenomena pointing to that conclusion. Now, with much less than 100 feet, with 60 or 70 feet, of submergence, Loch Ness would be an arm of the sea, and all the low ground around Inverness would be part of the sea-bottom,—comparatively shallow no doubt, but still such a wide sheltered bay as would likely be favourable to marine life. With a submergence of this limited degree it seems quite evident that the ice (assuming now that it was ice issuing from the Great Glen, and curving round in this direction) must have passed over a great part of the sea-bottom ere reaching this spot.

Slope of the Ground.—Here we may mention a circumstance by which we think the likelihood of the ice having transported marine remains with it in its progress hitherward is materially increased. We refer to the very gentle and equable slope of the ground all the way up from the sea-level to this part of the valley of the Nairn. No doubt this may be due partly to the action of the ice itself on the underlying sandstone, but having been brought about in whatever way, we are entitled to take it into account as one of the

* *Transactions*, vol. ix.

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conditions of the case. This feature caught our eye from various points of view all around, reminding us, in fact, of the long gentle slope from the neighbourhood of Carnarvon to the summit of Moel Tryfaen.* And, as we remarked with regard to that instance, though we have good proof that the ice, if in sufficient mass, and with sufficient body and weight behind it, can pass up far steeper gradients than those now spoken of, yet probably the steeper the gradient the less likelihood there is of anything in the shape of marine organisms being transported by it; these would probably be caught and crushed by obstructions in the way. But (as we have seen the proof of the *upward* as well as *eastward* course of the ice in this quarter) if we assume there was, from the sea-bed to Clava, a rise of 500 feet in ten miles, this is equal to 50 feet per mile, or 1 in 100, which would be so slight as to be almost imperceptible, and when compared with the known elevations to which boulders have been carried in short distances, seems to present, we may say, the minimum of difficulty.†

All these points are in favour of the ice-transport theory. We pass on now to consider

The Organisms.—While the clay itself, so far as we can judge, has been formed in deep and comparatively still water, it is to be noted that the most numerous examples of shells found in it are of species which live near the shore, or in moderately shallow water, *e.g.*, *Littorina littorea*, *Mytilus edulis*, and others, whose habitat is chiefly between high and low water mark. This so far confirms the probability of their having been transported from part of the level shallow tract between the Moray Firth and the present bed of Loch Ness. Associated with these, however, are other species belonging to deeper water, as *Leda pernula*, *Natica*

* *Transactions*, vol. ix.

† We may here briefly repeat some of the facts stated in a previous paper. The American Geologists give instances of boulders which "must have travelled over 60 miles and been raised over an acclivity of 3000 feet altitude." Others of which the parent beds are but 12 miles distant and yet about 3000 feet lower. (Wright's "Ice Age in North America," p. 217). The gradient thus varied from 50 up to 250 feet per mile. In other cases blocks have been carried up a slope of 7° two miles long to a height of 1300 feet; and in one place up a slope of 16° one mile long to 1400 feet (M.S. Gov. Report "Geology of Pennsylvania"). In Norway similar instances are known; and in our own country—in Galloway—Mr. Horne found boulders of granite about 500 feet higher than the rock *in situ*. In the Isle of Man, also, granite boulders have been carried to the summit of South Barrule, showing a rise of over 800 feet in 1½ mile (*Quart. Jour. Geol. Soc.*, August, 1892).

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Grœnlandica, *Buccinum undatum*, *Astarte compressa*, species inhabiting from 5 to 10 down to 80 or 100 fathoms. I do not wish to make too much of this, as shallow- and deep-water species often get mingled to some extent on our shores from ordinary causes; but, so far as I am aware, such cases usually occur on low and very gradually deepening coasts. Here, along the sides of this valley, we can hardly suppose there could be much extent of shallow water during a time of submergence, and I therefore think it significant that the great preponderance of the species should indicate shallow-water conditions.

Their State of Preservation.—But from the fact that many of the shells are in a tolerably perfect condition, an objection may be raised to the supposition of their having been transported by land-ice. It would be easy to show, however, that this objection is not very conclusive, for even in the known instances of "shelly till," as in Caithness, Lewis, &c., many of the shells are well preserved. Messrs. Peach & Horne, indeed, were so struck with the perfect condition of many of the shells in the Boulder-clay of Caithness, that they suggested it was "highly probable, from the appearance presented by many of the fragile shells, that they were *frozen into* the ground-moraine, and so escaped destruction."* And we think Mr. Lamplugh has also suggested that in some cases the mass of clay in which shells were imbedded may have been transported *en masse* in a frozen condition, and so the contents would be practically untouched.

Illustrations.—Explain it as we may, the fact remains that, sometimes at least, very delicate shells are found uninjured which must have been transported by this means. As illustrating the combined *power* and *gentleness* of the transporting agent, we may note that thin fragile masses of chalk of considerable length are found imbedded in the drift at Cromer; and how they could be conveyed thither, and imbedded with so little fracture, has been a puzzle to geologists. The surprising thing, says Mr. Mellard Reade, about these boulders is their "length and extreme tenuity," and the remarkable way in which they have been preserved unbroken. But, he admits, "it stands to reason that the transporting agent, whatever it may have been, could convey them

* "On the Glaciation of Caithness," in the *Proc. Roy. Phys. Soc. Edin.*, vol. vi.

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many miles as easily as one mile."* And Dr. J. Geikie observes that "once imbedded in the ice, stones and boulders might travel for hundreds of miles without suffering abrasion."† If so, perhaps shells, or patches of shelly-clay, might sometimes be transported uninjured in the same way for a dozen or a score of miles.

But are they, as a rule, in perfect condition?—At the same time, it must be admitted that in general, the majority of shells found in such circumstances—either imbedded direct in the Boulder-clay, or in patches of shelly-clay intercalated with it—the majority, we say, are more or less crushed and broken, as might be expected. Mr. Fraser's account of the deposit is above suspicion; he is a most careful observer, and accustomed to report exactly what he sees. But we know that any one finding a bed of shelly-clay is naturally anxious to get as many perfect specimens as possible for purposes of identification, and is apt to overlook the proportion of broken or imperfect ones that may be associated with them. Mr. Fraser's statement is that "many of the shells are quite entire, though in a very delicate condition,"—which implies that some, perhaps many, perhaps even the majority, were broken. And this is quite confirmed when we look at the lists made up by Mr. Jamieson and Mr. Robertson from the specimens forwarded to them for identification—presumably to some extent *picked* specimens, the *best*, and not the *worst* that were found. Casting our eyes down the lists, we read—"numerous fragments," "a valve," "three or four, and fragments," "fragments of several," "one in pieces," "a small fragment." Mr. Fraser states, at the same time, that many of the shells had their epidermis or outer skin well preserved, showing that they had not been subjected to abrasion; but from what we have already said, this seems to be quite possible. Some shells seem to escape entire, while others are more or less injured, and a great many are crushed to fragments.‡

The Clay.—We have still to add a few words with regard to the clay itself. It is not formed from the waste and washings of the Old Red Sandstone tract on which it is placed; its materials

* *Quart. Jour. Geol. Soc.*, vol. xxxviii.

† "Great Ice Age," 2nd ed., p. 208.

‡ Mr. Lamplugh found in the glacial shelly-clay of British Columbia shells which were actually in a better state of preservation than those he could gather on the neighbouring shore.

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have evidently been brought from some distance. It is described as "a stiff blue clay, or silt, containing a slight proportion of small stones, mostly well-rounded and water-worn, and all—with very few exceptions—consisting of gneiss rock." And Dr. Ivison Macadam, who examined it, reported that it "bears a close resemblance to clays from mixed gneiss and schist districts." So that there seems to be a difficulty in supposing it to be an ordinary marine clay formed by the sea where it is now found.

Conclusion.—If there is any weight in the considerations now submitted—if the various objections stated to the "submergence theory" seem to be well-founded, and the several points urged in favour of the "ice-transport theory" be in any degree reasonable or probable—then I think I may fairly claim with regard to this instance at Clava, as I did with regard to that at Chapelhall, that it cannot at present be received as a satisfactory proof of submergence.

II.—Other Northern Localities.

[*Abstract.*]

The author briefly noticed the "red clay" in Aberdeenshire, containing a few fragments of shells, which had been described by Dr. Jamieson a good many years ago, and supposed by him to be the result of deep-sea conditions immediately taking the place of the ice as it melted away.* Details must now be reserved; but Mr. Bell pointed out several objections to this conclusion; and, reviewing the whole evidence, ventured to suggest the presence of "glacier lakes" formed by the ice passing along the shore (as Mr. Jamieson had shown it to have done), and so blocking the transverse valleys. He had submitted his reasons in this matter to Mr. Jamieson himself, who in the frankest manner had admitted the probability of such an explanation. He (Mr. Bell) was disposed to think that the same explanation would yet be found to apply to other localities where such deposits occurred, and might be the solution of most of the difficulties connected with them.

* *Quart. Jour. Geol. Soc.*, vol. xxxviii.

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SUPPLEMENTARY NOTE.

Since this paper was read to the Society, the substance of it and of the preceding paper on Chapelhall was communicated to the British Association at the Edinburgh meeting, 1892. Chiefly through the warm interest taken in the subject by Mr. Horne of the Geological Survey, a committee was appointed for the investigation of these "high-level shelly-clays" in Scotland—with Mr. Horne as *Chairman*, and the present writer as *Secretary*. Two reports of that committee have now been issued, viz., on Clava (1893), and on Chapelhall (1894).

1. *Chapelhall.*—Taking the latter first, it has to be stated that the result of the investigation was *negative*. After taking down the "cradling" of the well in which the "deposit" was reported to have been found, and sinking six bores in different positions all around it, the committee were unable to find any trace of th "shelly-clay." They also sank a bore from the bottom of the we. to verify the statement that the "Till" rested on rock at a depth of 24 feet; but after going down nearly 31 feet, no rock was found. The committee apparently have no explanation to offer of these discrepancies; they merely record the facts. Meantime, this Chapelhall instance is being quietly "dropped" by geological writers who formerly made much of it.

2. *Clava.*—The Report on this "bed" was of much greater length than that on Chapelhall. Numerous parcels of the shelly-clay, and also of the associated deposits of sand and Boulder-clay, were examined with much care, chiefly by Mr. David Robertson, whose great experience and thoroughness in such work are well known. As regards the section, the principal additions to our knowledge resulting from the operations of the committee are—(1) That the shelly-clay at the "main pit" is 14 to 16 feet in thickness, and that underneath it are, first, 15 feet of "coarse gravel and sand," and then 21 feet of "brown clay and stones" (probably these should be put together as "Boulder-clay"), the whole resting on the Old Red grit of the district. (2) In the overlying Boulder-clay and sand no organisms were found. (3) The "blue clay" seems to thin out on both sides of the "main pit." At 130 yards W. a small patch was found, only 15 inches in thickness; at 196 yards W. it was not found. At 30

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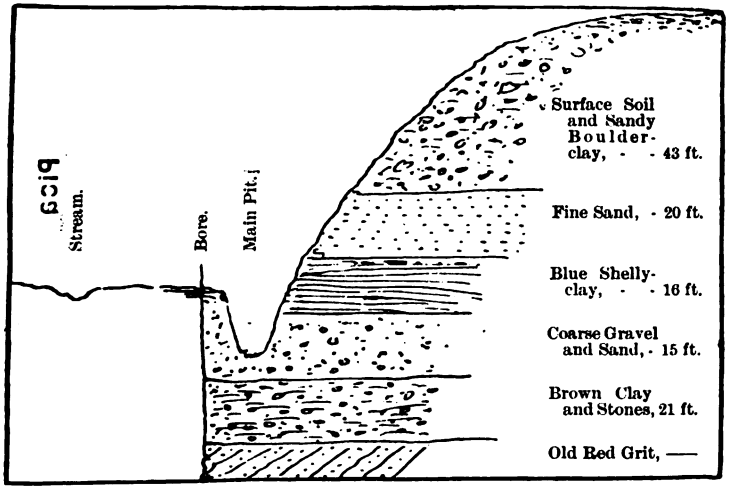
yards E. a similar clay was found, 2½ feet in thickness; at 61 yards E. it was not found. Only one of the bores yielded evidence of shelly remains. The difference in level of the clay between


Burn
Stream.
Bore.
Main Pit.
Surface Soil and Sandy Boulder-clay, - - 43 ft.
Fine Sand, - 20 ft.
Blue Shelly-clay, - - 16 ft.
Coarse Gravel and Sand, - 15 ft.
Brown Clay and Stones, 21 ft.
Old Red Grit, ——

SECTION OF CLAVA BEDS.

the two extreme points was 19 feet. (4) A striking fact brought out in the Report is the difference in composition between the shelly-clay and the gravel and Boulder-clay beneath and above it. While these latter contain on an average 70 to 80 per cent. of Old Red Sandstone, and only 20 to 30 per cent. of gneiss, schists, and granite; in the shelly-clay, on the other hand, the proportions are almost exactly reversed—it contains only 18 to 20 per cent. of the Old Red, and fully 80 per cent. of the more ancient rocks. This is a remarkable fact, which must surely be kept in view in any theory of its origin.

In preparing the Report, a divergence of opinion became apparent among the members of committee, the majority holding that the deposit is really *in situ*, and indicates a submergence of over 500 feet; while a minority (chiefly for such reasons as are stated in the foregoing paper) held that this conclusion is still unproved, and that the difficulties connected with it outweigh those on the other side. It is not our purpose at present to re-argue any of the points; we leave the reasons we have set forth

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to the consideration of our readers; and shall only add the following sentences from the "Note by the Minority," which appear to sum up their views in very fair and moderate terms:—

"The ice-transport theory (whatever difficulties may attach to "it) has at least this point in its favour, that the deposit is quite "in the track of ice which would almost certainly pass over part "of a former sea-bed in its progress. It has also this other "point, that the shelly-clay consists almost wholly of materials "derived from some distance, differing from those in the immedi-"ate neighbourhood, and from the Boulder-clay and gravel both "above and below it. Further, though the clay itself suggests "deposition in deep and comparatively still water, the shells and "other organisms it contains are almost entirely of littoral species; "and though the stones in it are in general rounded and water-"worn, some distinctly striated are associated with them, and all "occur promiscuously imbedded in this fine unstratified clay, "without, as a rule, even a streak of accompanying sand or "gravel. Mere submergence seems inadequate to account for "these facts. And we venture to say that to assume, first a "submergence of over 500 feet, then a re-elevation to about the "old level, with a return of glacial conditions, much the same as "before, is to hang an immense series of changes upon the (as "regards interpretation) more or less doubtful evidence before us."

Since the publication of the Report, the present writer has been confirmed, by further observations, in the very great probability of the explanation, suggested at the end of the foregoing paper, (with reference to "Other Northern Localities,") as applicable to Clava also, and believes it contains the key to a satisfactory solution of the problem. [*November*, 1894.]

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No. XII.—A Ramble up the Maich Water. By James S. M'Lennan.

[Read 9th November, 1893.]

A RAMBLE up a river valley has attractions to men of varied tastes and divers pursuits. The naturalist, bent on acquainting himself with the various forms of animal life, finds here a suitable locality for his observations; the botanist can obtain a great variety of objects to arrest his attention, call forth his curiosity, and satisfy his thirst for knowledge, in the trees, plants, ferns, and lichens which adorn its slopes, clothe its fields, fringe its cliffs, and cover its rocks; and the lover of the beautiful in scenery can find much to please him; and if with the eye to appreciate, he has the hand to pourtray the scenes he surveys, many of them will afford him delight to paint, and will give delight by being painted. The disciple of old Izaak Walton will, if the waters of the stream flowing through the vale be free from impurities, often resort thither to pursue his solitary amusement; and while doing so, and when his sport is ended, will confess that fishing amid such scenes, even though the take be small, is "idle time not idly spent." It would even seem, if we are to credit the tuneful sons of genius, that river valleys are the peculiar haunts of the Muse, for one well qualified to decide this point has said in words much admired by Coleridge:—

> "The Muse, nae poet ever fand her,
> Till by himsel' he learn'd to wander
> Adown some trotting burn's meander,
> And no think lang;
> Oh sweet to stray and pensive ponder
> A heart-felt sang."

But last, and not least, such localities possess great attractions for students of the stoney science. The scaurs of Boulder-clay, the mural precipices with their varied strata and interesting fossils, the exposures of igneous rock in masses, dykes, and floats, the striated rock-surfaces of the glacial period—all these, and many more, form delightful subjects of observation to every votary of field geology.

The Maich is a small mountain stream, which, rising near the foot of Mistylaw—one of the highest of the Kilbirnie range, and the highest hill in Renfrewshire—flows for a distance of some seven miles in a south-easterly direction, and falls into the north-western end of Kilbirnie Loch. For the greater part of its course it forms the boundary between the counties of Renfrew and Ayr.

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The valley extending from Kilbirnie station to Castle Semple had, at no very distant date, its lowest portion covered by the waters of a lake some six miles in length. This lake has been gradually lessened in area by the materials silted into it from the time when the slopes of the Boulder-clays and glacial drifts were exposed to the denuding action of rains and rills, and by the debris carried into it by the Maich and Calder Waters on its western slope, and by the Rowbank, Mains, and Willowyard burns on its eastern side. A portion of it known as the Barr Loch was artificially drained about the beginning of the present century, and now forms excellent cornland. South of this last-named loch lie "the Meadows," through a portion of which the Glasgow and South-Western Railway has been formed. In the construction of the line at this place great difficulty was experienced on account of the soft and muddy nature of the ground, and it was only by driving down long piles that a firm and permanent roadway could be made. Kilbirnie and Castle Semple Lochs, as we know them, are the remaining fragments of this once extensive lake, and they are united by a sluggish stream called the Dubs. The former of these lochs is 1½ mile long by ½ mile wide, with a varying depth reaching as much as 33 feet. It is 94 feet above sea-level, and lies on the water-shed between the waters carried to the Clyde by the Dubs and the Black Cart, and those borne to the sea at Irvine by the Garnock. At its southern end its extent has been somewhat lessened by the heaps of rubbish from the Glengarnock Ironworks which have been run into it. Nearly twenty-three years ago three crannogs, or lake dwellings, were found in this portion of the loch, and two canoes, each formed of a single oak-tree, were also discovered in it. One of these, 18 feet long by 3 feet broad, and nearly 2 feet deep, contained a three-legged bronze pot and a lion-shaped ewer. The pot is 11 inches in diameter across the mouth, 14 inches high, and weighs 28 pounds. The ewer is larger and more ornamented than one figured and described in Wilson's "Prehistoric Annals of Scotland," and is 8½ inches high, 8 inches long, 8½ inches round the body, and weighs 4 pounds. "It is made of yellow bronze, and seems to have been used for holding liquid."

In starting our ramble up the Maich, from the place where it enters Kilbirnie Loch, and walking on to the Carse Bridge which

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carries the Kilbirnie and Lochwinnoch highway across it, we observe that its channel has been cut through the alluvium brought down from its upper reaches. This, as shown by an adjoining section, consists of 2 feet of fine earthy matter, and 4 feet of gravel intermingled with rounded boulders varying from 1 foot to 2 feet through their longer axes. The gravel and boulders are mostly composed of porphyrites and amygdaloids, with a few sandstones and ironstones, and occasional small pieces of dark-coloured shales. These last, from their fragile character, were ill-qualified to sustain the rough usage they must have undergone in the rocky bed of this rapid stream, so they are small in size and few in number. I failed to note any limestones in this exposure. This alluvium has been spread over a considerable area, and now forms the best soil of three farms all bearing the name of "Carse." The hilly nature, and heavy rainfall, of the Maich basin, and the consequent velocity and size of its current, along with the width and depth of the gorge it has hollowed out, can well account for the extent of the alluvial matter which has been deposited by it.

Passing Carse Bridge, we come upon the lower Boulder-clay, through which the stream has cut down to the white sandstone which here and for some distance further forms its bed. This sandstone has its upper surface roughened and indented with circular depressions, and some of its thinner layers present examples of what may be annelid borings.

The clay presents the usual colour which it bears over Carboniferous areas—a dark grey—caused by the grinding action of land ice over the dark shales and coals of the district. "As this vast ice sheet moved forward it rasped and planed down the asperities of the rocks over which it passed, leaving their surface smoothed and polished, and covered with parallel rectilinear striæ and grooves like those on the rock-floors in present Alpine regions." Examples of these striations can be seen farther up the stream near the farmhouse of West Auchenhain, and still better ones are found on a rocky ridge a little to the west of the height crowned by the cairn erected to the memory of the late Mr. Cochran-Patrick younger of Woodside and Ladyland. Several instances of the smoothed and rounded ridges known as "drums" are also met with—that which has the farmhouse of Barrhill on its summit forming a prominent feature in the landscape.

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In our upward course the gorge deepens, and amid the trees which grow on its northern slope we notice the remains of several "ingaun ees" which reminds us that we are on the coal measures of the Dalry basin. Close below the Carse, an exposure of the "main" coal is seen running along the southern bank for 16 yards. This coal is 3 feet thick, is underlaid by black shales, and surmounted by sandstone layers of 4 feet, shale of 1 foot, and sandstone beds of from 12 to 15 feet in thickness. There is an interesting example of a fault seen above the main coal exposure, both sides of it being well displayed, and the broken and compressed character of the sandstones and shales contiguous to it being very evident.

A little further up the stream this coal is again seen protruding from a bank of sandstone. Its position has been caused by a fault which has given it an upthrow of several feet, but it lies quite level, and the western side of the fault is well seen. The superincumbent sandstones and shales are well represented, and the section with its grass-covered top is nearly 50 feet in height. This coal is supposed to crop out in an eastern direction parallel with the "smiddy" coal, which is met with 30 yards above the first waterfall. In the Dalry basin this coal is found 10 fathoms higher up than the main coal, and is 2 feet in thickness. Here also the black-band ironstone—15 inches thick—is met with 30 fathoms below the main coal, and we discover it a little further up—a short distance below the first waterfall, where the stream rushes over a ledge of white sandstone some 6 feet in height. This ironstone has a considerable area, as it has been wrought more than a mile to the east of its exposure on the Maich, whence it extends in a south-western direction—by Kilbirnie and Dalry—for a distance of nearly 8 miles.

Continuing our upward walk we come upon a fine display of strata on the northern bank, consisting of a 5 feet post of black shales at the bottom, then 4 inches of clay ironstone, 2½ feet shales, 3 inches of ironstone, 10 feet of dark shales, 2 inches of ironstone, 9 feet of shales, and 10 feet of sandstone on the top. This section dips to the south at a low angle, and at its highest part brings to view a 6 inch seam of coal resting on 2 inches of fireclay, then 4 inches of ironstone, 2 feet of black shales, and, lying exposed in the river-bed and showing a light purple colour, some 6 inches

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of clay ironstone. These ironstones, when subjected to the action of the air, generally bear a dull brownish colour, but the purple tint shown by those in the bed of the stream here may be caused by the peat-coloured water flowing over them. Where exposed to the action of the atmosphere alone the colour is not so pronounced. Some 300 yards further up this ironstone is seen stretching from side to side of the stream, lying at a gentle slope, and presenting an uneven surface; it reminds one of a well-built "damback." It occurs again a little higher up, lying nearly level, and forms the bed of the stream for a considerable distance. This exposure recalls to mind a similar one I have seen in the channel of the Nethan Water near Tillietudlem Castle.

One of the best sections on the banks of the Maich is met with nearly direct north-east of Barrhill farmhouse, where are displayed in succession some eighteen different layers of shale, coal, and ironstone, in fine form and of considerable extent. The sandstones, which are found at the top of the last-mentioned exposure, are awanting here. About 6 feet from the bottom this face presents a 3½ feet bed of dark shale, the lowest part of which is almost composed of mussels, and this overlies a 3-inch band of ironstone containing similar shells. At the upper end of the section a Miocene dyke, 5 feet in breadth, crosses the stream, and on its western side rises perpendicularly for 12 feet. From the diversified forms assumed by the rock in cooling it resembles a piece of rudely built cyclopean masonry. A second and similar dyke, 20 feet broad, runs across the stream a little higher up.

Continuing our upward course we arrive at a bend of the river where the Carboniferous limestone appears, and which at Broadstone, in the parish of Beith, attains a thickness of 100 feet. In a paper read before this Society,* it is thus detailed:—A bed of white clay, 1 foot; thin coal and shales, 3 feet; main limestone post, 5 feet; two-feet limestone post, 2 feet; calcareous shales, 2 feet; blue limestone post, from 2 to 13 feet; coarse sandy limestone, from 4 to 10 feet; shales, 40 feet; and Hillhead limestone, 40 feet. In the section we have now reached, however, there are more than 80 feet of strata awanting, and the dark shales, 11 feet; the main post, 2 feet; the calcareous shales, 2 feet; the limestone post, 3 feet; and the underlying coal are all that remain.

* *Transactions*, vol. iv.

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It is interesting to note the varying depths at which the lower limestone is found in this portion of the Dalry basin, as these give evidence of a very striking change of level. It has been stated that if a line were drawn across the valley from the Maich to Broadstone the limestone will be found cropping out at both places at a height of nearly 300 feet above the level of the sea; while at the Carse, in the middle of the valley, the surface is 90 feet over sea-level, and the position of the limestone 500 feet below it. Thus, in a distance of not more than four miles, there is a difference of 800 feet in the position of this limestone.

In our ramble thus far up the stream we have seen exposed about 700 feet of strata belonging to the coal measures, but the fossils so far as noticed are neither abundant nor well-preserved. Some 12 yards above the limestone exposure the igneous rocks come to view, and all the remaining course and basin of the Maich is occupied by them. Their junction with the coal underneath the limestone is not visible. They consist here of trap tuff, greyish red in colour, and in some places crossed by what looks like calcite. A boss of volcanic agglomerate in the middle of the stream attracted my attention, and I spent some time extracting the small, smoothed, gravel-like stones enclosed therein.

The Maich basin is situated on the eastern slope of the hills which extend from Ardrossan to Lochwinnoch. These, along with the uplands of Renfrewshire south of the Clyde, are a continuation of the elevated ridge of trap heights, which include the Campsie and Kilpatrick Hills, and reach to within a short distance of the town of Stirling. They are all of volcanic origin, similar in structure, and of the same geologic age, with the exception of the Miocene dykes which traverse them. They are composed of a great succession of lava flows, chiefly of the kind known as porphyrite, interbedded with layers of fine ash, or tuff, and coarse volcanic agglomerate. These trap rocks in their eastern and western areas are found to overlie the calciferous sandstone series.

The trap rocks have been divided into two groups—the *acidic*, those in which silica predominates; and the *basic*, those in which the earthy bases and metallic oxides are in excess. The former class have less specific gravity than the other, and are supposed to have been erupted from a lesser depth beneath the surface than the basic group. It is stated by Professor Judd that in times of great

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volcanic activity in Scotland the earlier lava flows were generally of the acid group, whilst those erupted at the close of the periods belonged to the basic class, and I believe that the bedded traps of the Ayrshire hills near Largs chiefly belong to the former variety. These rocks consist of many varieties of felstones, varying in texture from compact to porphyritic and amygdaloidal felstones. These differences have probably been caused by the rapidity or slowness with which the rock cooled from a molten condition, as, from experiment, we know that the same mass will yield a compact basalt when suddenly cooled, and when subjected to a slower cooling it will produce a soft and earthy tuff. The amygdaloidal structure is more commonly found among the felspathic or acid group than in the doleritic or basic class, which seems to imply that the former kind has had more aqueous vapour locked up amongst its mineral elements than the deeper-seated basic lavas.

Although the trap rocks comprising the hills of Ayrshire and Renfrewshire mostly belong to the acid group, still examples of the basic lava-flows are met with in the sheets and dykes of dolerite of supposed Miocene age. It is thus to the long-continued action of the great palaeozoic volcanoes of Western Scotland that the formation of these extended ranges of hills is due.

Many of the felstones of these hills, as those of the Maich basin, have a brownish and, in some places, a very distinct red tinge of colour. In the bed of the Garnock, two miles above Glengarnock Castle, a fine exposure of this red felstone is seen. The colour is due to the presence of the peroxide of iron in the rock, and to the complete oxidation of its iron elements. In several places we noticed that these rocks were interstratified with layers of volcanic ash of a greenish, or grayish-green, colour. Near Laigh Glengarth, on the southern bank of the Maich, is a good section of this ash, nearly 15 feet high.

We occasionally pick up small pieces of barytes in the bottom of the stream, and a little above Ladyland House, on the northern side, a vein of this mineral, 10 inches thick, can be seen. In the basin of the Calder Water, farther to the east, barytes occurs in such mass that it is quarried and ground into a powder, which is said to be used almost entirely for the adulteration of white lead.

In our ramble we now arrive at the well-wooded grounds of

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Ladyland, which, on their northern side, are bounded by the Maich. We notice the luxuriance of the trees—mostly hard-wood—with their size of trunk and "wide protection of bough" indicating the fitness of the soil derived from the decomposition of the trap rocks, with their mineral ingredients—lime, soda, potash, and iron—to produce such richness of vegetation.

Here, also, are the highest and finest of the waterfalls to be met with in the course of this stream. As showing the steep rocky character of this rivulet, it may be mentioned that in 5 miles of its course it flows over no less than nine waterfalls, varying in height from 4 to 12 feet; and of these two are met with in the sandstones, and the rest in the porphyrites. After passing the reservoir which supplies Lochwinnoch with water, the banks of the stream are bare and treeless, and the exposures of rock similar to those we have already passed. Several Miocene dykes occur, and some interesting specimens of potholes. These latter are circular in form, of a foot or two in depth, and some of them contain the rounded stones which have formed them, through the continuous action of the water producing a circular motion, and consequent friction, sufficient in time to excavate the holes as we now see them.

Close to the shepherd's house at Cock-ma-lane, we reach the eighth waterfall—a mass of dark porphyrite, surmounted by a ridge of reddish-grey amygdaloid—above which the stream flows through an open moor in a shallow channel with grass-covered banks. Higher up the rocks in the bed of the stream exhibit in some places a pale, almost whitish colour, but above the last waterfall its course presents no further interest to the geological rambler.

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No. XIII.—On a Bed of Fossil Plants, and one of Limestone with Magnesia, in the Calciferous Sandstone Series, at Meikle Busbie, near Ardrossan. By John Smith.

[Read 12th October, 1893.]

Meikle Busbie is two-and-a-quarter miles north of South Beach, Ardrossan, and the rocks in its vicinity belong to the calciferous sandstone series, and to the trap which overlies these beds.

Immediately to the north of the farm-steading there is an area of porphyrite which extends in a north-west and south-east direction for about two miles, with a breadth of three-quarters of a mile. On the north-east side this trap is sharply cut off by a fault, which brings down the Carboniferous limestone series against it. On the south-west side it lies above the calciferous sandstones at an angle of 40°, and has highly indurated the beds with which it has come in contact. In the trap area several very prominent rocky knolls are dispersed here and there. A small quarry for "road metal" has been opened into one of these trap knolls at a point between the farm-steading and the Dalry and Ardrossan road. Where the plant-bed is seen on the side of the cutting made into the quarry the section is as follows, the strata dipping north-east at 40°:—

	Feet.	Inches.
1. Trap,	15	0
2. Light-coloured Shale,	0	6
3. Dark Sandy Plies,	0	3
4. Soft Dark Plies,	0	1
5. Fine-grained *metamorphosed* Sandstone, with *Plant-remains*,	1	2
6. Coarse altered Sandstone,	2	3
7. Light Shale,	1	4
8. Sandstone,	—	—

The trap at the top of the section, which is much weathered at the joints, is roughly columnar, containing veins and cavities filled with crystallized calcite. Some of the calcite is also weathered, and where it is so those curious striations or lines which cross the crystals obliquely on some varieties of calcite, but along which they will not cleave, are weathered into gutters and ridges, as are the cleavage lines. That some of the strata have been much altered by the trap is very well seen, especially in the plant-bed, which has the appearance of some kinds of quartzite.

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In the bed below it—a yellowish sandstone—there are small globes looking like iron pyrites, which, on closer examination, are seen to be a mixture of sand-grains and pyrites, the latter having segregated in the sandstone, and forcing the sand-grains slightly apart. These globes range up to an inch-and-a-half in diameter. When one of them is broken across, the sand-grains are seen to be mostly sharply fractured, showing that they are tightly fixed in the pyrites. I have previously seen pyrites in sandstone, but in much smaller nodules, and still mixed up with the sand-grains. In the Busbie section it is quite possible that the sandstone bed was at one time completely impregnated with pyrites, the globes being the undecomposed remains of it, the rest of the sandstone being full of ochre, left possibly from the decomposition of the pyrites, as specks of pyrite are here and there seen in it.

In the plant-bed specimens of plant remains are numerous, but it would be difficult to say, from their poor state of preservation, even to what genera they belong. Some of the stems or branches measure up to four inches in diameter.

Under the above section there are about 130 feet of strata which are not exposed, and then comes an exceedingly interesting bed of limestone, containing a notable percentage of magnesia. It has been worked for some years in a quarry close to the roadside, where a good section of it is at present to been seen. It is as follows:—

	Feet.	Inches.
1. Fine-grained Sandy Limestone, - - - -	7	0
2. Sandy Plies, - - - - - - - - -	0	1
3. Limestone Agglomerate,- - - - - -	12	0
4. Light Sandy Shale, with Nodules of Limestone,	5	6
5. Limey Sandstone, - - - - - - - -	2	8
	27	3

The thick limestone agglomerate (no. 3), contains 15 per cent. of magnesia, 4 per cent. of silica (mostly in the shape of sand-grains), and rather more than 1 per cent. of alumina; the calcined stone contains 26 per cent. of magnesia, and about 6½ per cent. of silica. It is a curious agglomerate of limestone pebbles, some more or less angular, but many well-rounded, and mixed up with these are pebbles of quartz, agate, sand-grains, and siliceous pebbles with an oolitic structure. Some of the limestone pebbles

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are of a very dark colour. These features are better seen in an older quarry than the above, some distance to the east of the farm-steading, where greater weathering has given the rock a yellowish tinge. The section in this quarry is as follows :—

	Feet.	Inches.
1. Yellowish Limestone, fine-grained and sandy, with a few pebbles,- - - - -	5	0
(Two feet of strata not seen), - - - -	2	0
2. Limestone, with numerous stratified plies, and pebbles of quartz, agate, and sand-grains,	8	0
3. Limestone, with occasional stratified bands, and similar pebbles to no. 2, - - - -	8	0
	23	0

The rock-face in this quarry being much weathered, the materials which build up the limestone look as if they had all been *drifted*, and not deposited from chemical precipitation, although it seems to have been originally formed in this way. The agates in it (all drifted), sometimes contain pyrites, and rents through it are filled with crystallized carbonate of lime. There are also dispersed through the limestone patches of sulphate of lime, which fill swallow hollows, both here and in the other quarry. These are very white, and so soft as to be easily scratched with the finger nail. The quartz pebbles in the limestone are bound so firmly in the matrix as to break across when the rock is quarried.

Towards the top of the limestone section in the quarry next the road thin lenticular bands of a siliceous sinter, or cherty material, are seen at one or two places. It runs up to two inches in thickness, is mottled in structure like some varieties of jasper, but it is difficult to say whether it is contemporaneous with the formation of the limestone-bed, or introduced after the latter had been formed. It does not always run parallel to the bedding of the limestone, which fact favours the idea that it was of subsequent formation.

I have visited the Busbie sections a number of times, but have never been able to detect any fossils in the limestone; and the quarrymen who kept a look-out for them have never come across any either. In a number of microscopic sections which I have prepared, not a vestige of a fossil is to be seen. Some of the limestone, when calcined, becomes almost black in colour, but in its natural state only an occasional pebble is seen to be of a dark hue. The cause of this I have not been able to determine.

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Under the limestone in the quarry next the road is a space of about thirty feet where no strata are visible, but in the burn below this position are to be seen :—

	Feet.	Inches.
1. Purple Shale, - - - - - - - - -	1	0
2. Limestone, with purple spots, and red and yellow blotches, - - - - - -	2	0
	3	0

The purple spots are just pieces of shale, similar to that above the limestone, which have been mixed up with it during its deposition. When rubbed down on sandstone these bits of shale fritter away, giving the specimens a vesicular appearance. The limestone itself is also tinged in parts with red and yellow colour, and it contains many sand-grains. Further down the stream, beds of sandstone of yellowish, reddish, and whitish appearance, and lower in the scale than the rocks above described, complete this interesting section.

These limestones, though not entirely free from joints, are remarkably so, compared with those fossiliferous limestones which lie above the trap, and this comparative freedom from jointing makes them very difficult to quarry. In the quarry next the road there is a strongly slickensided face, which shows that there had been a fracture and a differential movement in the strata in a north-east and south-west direction, dipping with the strata, which corresponds to similar slickensides in the trap quarry.

The Busbie limestones appear to be the representatives of the Ballagan beds, but the lime in this district, instead of being dispersed through a series of shales in thin bands and layers of nodules, has all been gathered together into one or two beds. In fact, this relationship appears to be very close, as at Ballagan Spout there is a sandstone under the hill trap which appears to be the equivalent of the sandstone under the trap at Busbie.

The late J. Wallace Young, in a paper read before the Society,* gave eight analyses of the Ballagan limestones, and in these the magnesia is seen to range from about 14 to about 17 per cent. As we have already seen, the Busbie limestone contains about 15 per cent. of magnesia, and in this respect does not differ much from the limestone of the Ballagan beds, but the latter is very fine grained.

* *Transactions*, vol. ii,, page 65.

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No. XIV.—On a Bed of Ironstone occurring in Trap Tuff in the Parishes of Stevenston, Dalry, and Kilwinning. By John Smith.

[Read 4th December, 1893.]

In the latter part of 1886 I found a bed of ironstone embedded in trap tuff in a natural exposure on Lugton Water, nearly opposite Montgreenan House, in the parish of Kilwinning. Although I had before passed this section several times I never dreamt that it contained a thick bed of ironstone, weathering having given it the appearance of a decomposing trap.

Shortly after finding this ironstone in the Lugton Valley I was able to trace it in the four undernoted localities:—

1. In the first cutting of the Caledonian Railway, south-west of Kilwinning Station, where part of it was laid bare during the progress of the railway works.

2. In the cutting of the same railway to the north-east of Saltcoats. This outcrop is now mostly covered over, but part of the ironstone can still be seen.

3. On the Saltcoats shore, 490 paces south of the mouth of Stanley burn, where part of it is seen outcropping from below a bed of light-coloured tuff or volcanic mudstone which underlies the bottom shales of the Saltcoats coalfield.

4. In the bed of the Dusk Water at Ravenscraig, two miles east-south-east of Dalry.

The outcrop in the Lugton Valley is certainly a very typical one, as in a small cliff on the west bank of the stream a full section is exposed, together with the strata both above and below it. The following is the section, which dips at 13° to the south:—

	Feet.	Inches.
Sandstone and Shale,	—	—
1. Coal,	0	10
2. Light-grey, very fine-grained Tuff or Volcanic Mudstone with stigmarian roots in the upper part,	3	0
3. Do., with harder irony patches decomposing into rounded nodules,	2	6
4. Grey Ironstone, decomposing like trap,	4	6
5. Reddish, fine-grained Tuff, Bole, or Laterite, some of it with harder irony patches,	3	1
6. Yellowish and greenish Tuff, with greenish and greyish very hard ironstone nodules in upper part (measuring so far as seen),	6	0

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The ten-inch coal is the lowest seam in the Upper Coal measures (so called) of Kilwinning. The vegetation from which it has been formed has grown on the pure tuff, not a particle of fireclay interposing between the two, and stigmarian rootlets are abundant in the top part of the tuff next the coal. The beds of tuff (nos. 2 and 3) are, properly speaking, only *one* bed, which becomes irony as it approaches the main ironstone bed. Where the irony bits of tuff are decomposed the carbonate of iron has been dissolved out, leaving little hollows. Some of the hardened bits contain minute specks of pyrites.

The ironstone bed itself is an intimate mixture of minute particles of crystallized carbonate of iron and very fine-grained light-grey tuff. It may be divided as follows:—

	Feet.	Inches.
Top part, with vertical burrows (?) ⅛ inch in diam. filled with the Tuff, - - - -	0	9
Ironstone, with few burrows (?), - - -	2	1
Ironstone, with numerous burrows (?) ramifying in all directions, but mostly in a horizontal one, - - - - - - - - -	1	1
Ironstone, with few burrows (?), - - -	0	7

What I have called "burrows (?)" have every appearance of having been worm-tracks through the ironstone when it was yet in a soft though firm state, and wherever these worms (?) have crawled the fine tuff or mud has followed them. On the other hand, if this curious structure has been caused by the rootlets of plants, none of the carbonaceous matter now remains, nor is there anything resembling the stems or foliage of plants in connection with them.

The irony matter in the tuff below the main bed is like that in the tuff above, it gets more abundant as the ironstone is approached. The light-coloured tuff above the ironstone is easily cut with a knife, but when it is heated to redness in an open fire it becomes converted into hornstone, and will then strike fire with steel like flint, and cannot be scratched with a knife.

The ironstone nodules in the bottom bed of tuff are exceedingly hard, and a bit can scarcely be detached from one of them by an ordinary geological hammer. Perhaps some of the iron in the green ones exists as silicate. They run up to 14 inches in thickness, and are often soldered together into sheets—"curly bands."

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I am indebted to a chemical friend for the following information regarding this ironstone. The raw stone contains:—

	Per Cent.
Iron, pure,	26·0
Oxide of Manganese,	·4
Lime,	1·5
Magnesia,	1·9
Alumina,	18·0
Silica,	19·0
Phosphorus,	·37
Carbonic Acid,	20·00
Water, combined,	7·0
Water, free,	1·5
Specific Gravity,	3·0

The ball ironstone in the bottom tuff is considerably richer than this, containing 28 per cent. of iron, and both qualities are in great measure carbonates. The best of it after being calcined gives 41 per cent. of pure iron, and an acre of the thick bed would yield about 14,000 tons of ironstone.

As to the exact geological position of this ironstone, it is about 10 fathoms below the main coal, which a little further down the stream is found reduced to a thin bed of columnar coke by a "floating" trap, and between the main coal and the ironstone position the Rae's Road coal is found to be in a similar condition. The whole tuff deposit will possibly amount to 10 or 12 fathoms, some of it being rather irony, and several sections are well seen on the banks of the stream. Further up the river the upper limestone is seen outcropping in the bed of the stream, but very much reduced in thickness to what it is at Dalry.

As to the genesis of this ironstone, I see no other explanation but that it was showered, in the shape of fine irony dust mixed with the tuff dust, from some neighbouring volcano into a quiet lake, where, in the shape of a mud-bed, it settled down on the top of the shower of reddish tuff which had come before it. It was probably thrown out in four showers, if we are to judge from the manner in which the worm burrows, or whatever they may be, occur in it. In the whole section, from the bottom of the coal downwards to the bed of the stream, there is not, so far as can be seen, the vestige of a particle of material which one could say had been drifted from a land surface.

In what shape the irony material was when it left the volcano

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is for chemists to say. It could scarcely be as a carbonate, and it has in all likelihood assumed that character where it now lies by absorbing carbonic acid, perhaps from the decomposition of confervæ, of which I hope to show some Carboniferous specimens at an early date. This carbonate then segregated into minute crystalline masses or spathose ore.

We know that many igneous rocks contain considerable quantities of iron, and if we imagine volcanic material to be thrown out in the shape of dust, which was afterwards sifted, first, perhaps, by wind, and then by water, we get all that is required to form a bed of ironstone like the one described.

These outbursts of volcanic tuff appear to have been periodic. Under the lower limestones there are great beds of this material, which have been bored into for 80 fathoms without bottom having been reached. A sample from one of these beds in the Dusk Water I have had analysed, and found it to contain about 20 per cent. of iron. This bed was a reddish bole or laterite, not unlike some of the bole beds in connection with the Antrim traps.

This ironstone has every appearance of extending in a bed, unbroken, except by faults and dykes, from the shore at Saltcoats, where it is seen under tide-mark, to Lugton Water, a distance of seven miles, and perhaps, on further examination, it may be found to extend considerably further.

In the "Explanation" of sheet 22 the officers of the Geological Survey say concerning the tuff deposit in which this ironstone occurs—"Between it [Rae's Road coal] and the limestones on the shore [at Saltcoats] lies a representative of the volcanic zone, which, everywhere in this northern part of Ayrshire, separates the Carboniferous limestone series from the Coal Measures. It is sometimes a dull grey compact clay, like a fine-grained tuff, containing rounded concretionary grains or nodules of spathose iron, and it may be traced eastwards to the Lugton Water above Sevenacres Mill, and again to the Annick and Kilmarnock Waters." But no mention is made of this thick ironstone bed, and so far as I know no writer on Ayrshire geology has ever noticed it.

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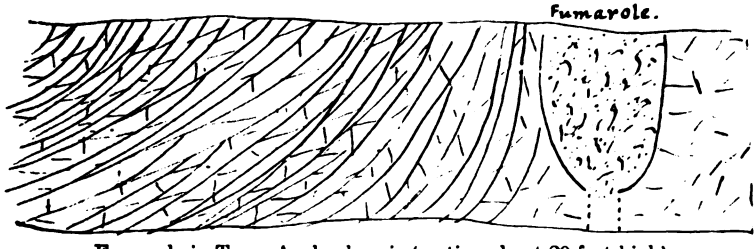
No. XV.—On a Mineral in a Fumarole at Auchenharvie Castle. By John Smith, Monkredding. With Two Sections.

[Read 11th January, 1894.]

At the old Castle of Auchenharvie, three-and-a-half miles to the north-east of Kilwinning, a thick bed of fine-grained, dense, hard, and heavy dolcrite (anamesite), intrusive in the upper Carboniferous limestone series, is at present being worked for road material.

During quarrying operations two fumaroles were exposed, the first one having been quarried away before I visited the place, but part of the second one still remains. The slabs of trap in the quarry curve upwards as they approach this fumarole, till they assume an almost perpendicular direction at its side.



Fumarole in Trap, Auchenharvie (section about 20 feet high).

When first laid bare the fumarole extended from the base of the quarry right to the top, and in outline closely resembled the interior of a lime draw-kiln. The bottom has not been cleared out, but from the manner in which it curves in towards its extremity, it looks as if its continuance in that direction was in the shape of a narrow pipe, for at present it is reduced to about five feet in diameter. The widest part may have been about three times as much, but its proportional size will be seen from the section. It was filled with greenish, ashy-looking material, and through the ash were numerous very irregular slag-looking veins of a mineral (the one under consideration), which I have never seen elsewhere, together with amygdaloidal patches.

This mineral varies in colour from dull white to dull purple, is much veined by narrow, dark purple veins, each having a lighter

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centre; and dispersed through it are numerous crystals, purple by reflected, but green by transmitted light. These crystals are about a millimetre in length, are of a twisted lozenge shape, and some of them are forked at the ends, giving the mineral a speckled appearance, and round each of them there is a very clear transparent band.

Section of Crystals.*

Thin sections of the mineral are rendered grey by numerous minute particles, and there are dark dusty-looking patches of microliths through it, as also sometimes in the contained green crystals. It tarnishes readily on exposure, looks as if it contained a large quantity of silica, strikes fire with steel, and is not scratched by a knife. Whether it has been introduced in a molten state, or deposited from solution in water, I am not able to say, although I am inclined to think the former has been its method of introduction amongst the green, ashy-looking matrix.

Round the sides of the fumarole are numerous veins of calcite, mostly in the form of arragonite. In other parts of the quarry beautiful pink-coloured arragonite is sometimes got; amygdaloids of delessite occur sparingly in the solid trap, and bowlingite, mixed with calcite, is found in veins.

* The dark-shaded patches in this section represent the green crystals.

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No. XVI.—On the Protoconch of *Orthoceras*, and on the Evidence of its Remains in Certain Scottish Carboniferous Species, with Illustrative Specimens. By John Young, LL.D., F.G.S.

[Read 8th February, 1894.]

My attention was directed to a short paper in the August, 1893, number of the *American Geologist*, by Mr. J. M. Clarke, an American palæontologist, on the protoconch, or first chamber, of the shell of *Orthoceras*, in which the author says "divergent views in regard to the nature of the protoconch in the nautiloid genus *Orthoceras* have been expressed by Professor Hyatt and Dr. Branco, the principal investigators of the developmental phases of this genus. The facts recorded by both these eminent observers are, in the main, the same." Mr. Clarke also states that "Branco has considered as the embryonal shell, or protoconch, 'the anfangskammer' (a German term for the beginning of the first chamber), it being the conical or cup-shaped termination of the tube as usually found, and which generally bears upon its outer and distal surface a "*Narbe*" or cicatrix." He still further states that "this 'anfangskammer' of Branco is considered by Hyatt as likewise the first chamber, but of a secondary condition of growth, and not as the embryonal shell; while the '*Narbe*' or cicatrix is regarded as the remnant of the protoconch." The protoconch is described as a small shrivelled lump or scar on the end of the first chamber, and is assumed to have been composed of conchiolin—a fatty, plasmic sarcode, which formed the beginning or first life of the shell—Hyatt explaining that "this accounts for its almost invariable absence on most specimens, since such an organ must have been easily lost or destroyed. The lumps must consequently be regarded as the remnants of conchiolinous protoconchs, having elongated and narrow apertures; but probably they were, when in a living condition, much larger and more oval, and more similar to the protoconch of the ammonoids."

Mr. Clarke, in his paper, after describing the general appearance and nature of the protoconch, records the finding of a protoconch, of large size compared with others that have been found on a palæozoic form of *Orthoceras*. "It is semi-ovoid in shape, and

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shows no indications of shrinkage or other irregularity, and its distal extremity is perfectly smooth." He further states that "it is probable that this protoconch has been derived from a shell so young that atrophy and wrinkling have not manifested themselves as they may have done with the more mature development of the shell, and in his concluding remarks he states—"this, I believe, is the only recorded observation of the protoconch in palæozoic forms of *Orthoceras*."

Feeling interested in Mr. Clarke's remarks as to what he had found, I set myself to make a careful examination of such specimens of our Carboniferous Orthoceratites, contained in my own collection and in that of the Hunterian Museum, as had the first or oldest chamber of the shell more or less well preserved, and I am glad to state that I have been fortunate in finding what appear to be the remains of the "*Narbe*" or protoconch on specimens of three species of the genus, appearing on the first chamber of the shell as the remains or impression of an oval scar or cicatrix, with a narrow groove, seemingly the impress of a conchiolinous protoconch, similar to those mentioned in Mr. Clarke's paper. Had I found this cicatrix on only one example, I should have been inclined to think that it was an accidental marking; but when I found the impression on several specimens of three species of *Orthoceras*, always presenting the same form and planted on the same side of the shell, I felt satisfied that it was a natural marking, the impression of the protoconch or first cell, now no longer attached to the shells.

The three species of Carboniferous *Orthoceras* which show the scars thus noted are—*O. subcentrale*, de Koninck; *O. unguis*, Phillips; and *O. attenuatum*, Fleming. Possibly the impression may yet be found on some of the other species of *Orthoceras* in our collections which have the lower portion of the shell or first chamber well preserved. In my examination of specimens, so far as it has gone, I have only found the impression of the protoconch on what I am inclined to consider are young examples of the various species. On many other specimens of the same species, having their shells seemingly perfect to the first chamber, I have failed to find any trace of the cicatrix; but these may have belonged to older examples, in which the scars have been worn away by abrasion ere the shells were entombed in the sediments

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of the sea-bottom. Probably the protoconchs, from their delicate organisation and position on the first-formed chamber of the shell, would be very liable to be destroyed, so that we can only hope to find them on young examples which have been well preserved.

Their situation has been upon the inner face of the first chamber at the pointed end of the shell, and on its concave or ventral side. The cicatrix is generally oval in form, and about one line long by half a line broad, its longest diameter being parallel with the length of the shell. A narrow groove runs along the bottom of the scar, which is bounded on either side by a slightly raised lip or ridge, and thus presents the form and appearance of a small mouth slightly pointed on its upper end. In *O. attenuatum*, which has a much more slender and pointed shell than the other two species named, it is so small as only to be discerned by a pocket lens, or under a low power of the microscope. In the specimens I exhibit it will be seen that the cicatrix does not form a conspicuous object, so that observers who are in search of it will have to make a careful examination under good light before it can be detected.

I shall only mention, in conclusion, that I have found the cicatrix present on examples of *Orthoceras* belonging to the three species above noted, from both the lower and upper limestone series, the localities being the South Hill, Campsie; Gair, near Carluke; Orchard Quarry, Giffnock; and Roscobie, in Fifeshire.

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No. XVII.—Notes on the Occurrence of Ctenostomatous Polyzoa in the Carboniferous Limestone of Western Scotland. By John Young, LL.D., F.G.S.

[Read 10th May, 1894.]

Of the small group of somewhat obscure organisms which I exhibit this evening, some of the forms have been known, for at least twenty years, to those members of the Society who have been in the habit of collecting, and minutely examining, the smaller fossils generally found attached to the stems of crinoids, or more rarely to the shells, which occur in the limestone shales of certain of the quarries in the East Kilbride district.

Till about 1870, little or nothing seems to have been known of the nature or zoological affinities of these fossils; but in 1877, Dr. H. Alleyne Nicholson and Mr. R. Etheridge, junr., contributed a joint paper to the *Annals and Magazine of Natural History*, on some peculiar parasitic, or incrusting organisms, found in the Devonian rocks of Ontario, U.S.A., and in some of the Carboniferous rocks of Scotland. The title of their paper was, "On *Ascodictyon*, a new provisional and anomalous genus of palæozoic fossils." The authors state that "after a very careful examination of a considerable number of specimens of the singular organisms that we have grouped together under the name of *Ascodictyon*, and after taking the opinion of several of our fellow-workers, we are still unable to express a positive opinion of their precise zoological position and relationships." The "fellow-workers" referred to were Dr. Strethell Wright, Professor Huxley, and the late Mr. H. B. Brady, none of whom, it seems, were able at that time to throw any light upon the true nature or affinities of these organisms. I may here mention that before the appearance of this paper I had, in 1874, sent a series of specimens of some of these incrusting organisms to Mr. H. B. Brady, who was at the time engaged upon his "Monograph of the British Carboniferous Foraminifera,"* and I did so because I thought he might find amongst them some organisms related to this group. I am very glad to state that he was able to do this, and that the genus *Stachia*, which he then established for the reception of some of them, is represented by some half-dozen

* Palæontographical Society, 1876.

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new species. Mr. Brady states that in his examination of these minute incrusting forms he had to set aside, as unknown to him, several doubtful ones; and it seems it was amongst some of these latter that *Ascodictyon radians* was afterwards detected by Nicholson and Etheridge, and was figured and described by them.

At the same time I was also in correspondence with the late Mr. G. R. Vine, of Sheffield, who had long, zealously, and enthusiastically, up to the period of his death, 8th August, 1893, worked amongst the British Fossil Polyzoa, and it was from him that I first heard that the organisms known as *Ascodictyon* were beginning to be looked upon by himself and by one or two other observers as related to the ctenostomatous group of the recent polyzoa, of which up to that time no fossil forms had been correctly identified or described. As time went on Mr. Vine was strengthened in his conclusions as to the ctenostomatous relationship of *Ascodictyon* by the discovery of many specimens in the Upper Silurian limestone shales, of the Wenlock strata of Shropshire, and also by the findings of Mr. E. O. Ulrich, State Geologist of the United States of America, in the Lower Silurian shales of Cincinnati, who from them figured and described another form related to *Ascodictyon*, placing it, however, in a new genus named *Rhopalonaria*. Mr. Ulrich more recently associated Mr. Vine's name with another new and distinct form, which he also included amongst the ctenostomata, and named *Vinella*. He also stated regarding the same genus, that Mr. Vine "was the first to suggest the relation of his own new genus *Rhopalonaria*, and *Ascodictyon* of Nicholson and Etheridge, to the ctenostomatous polyzoa." The late Mr. George Busk, one of the greatest of our British investigators of the living polyzoa, in his "Challenger Report" refers to Mr. Vine's work, and to the fact that he was amongst one of the first to throw out a hint, as he terms it, that *Ascodictyon* was related to the recent ctenostomata.

I may here indicate the chief characters of the ctenostomatous group of the polyzoa, as seen in living specimens, and as noted in Professor H. A. Nicholson's "Manual of Zoology." "The cells arise from a common stalk, and are thus placed in communication with one another," and "their mouths are terminal and furnished with a setose fringe for their closure." In some of the recent genera, as in that of the *Valkeridæ*, the zoarium in its growth is found to

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exist both as erect and repent stems in several of the species, and in some instances it is seen to be jointed at intervals, this latter character being also well seen in many of our Carboniferous specimens.

Mr. Vine, in a paper contributed to the *Proceedings of the Yorkshire Geological and Polytechnic Society* in 1891, reviewed the work done by Mr. Ulrich and himself amongst the fossil ctenostomata up to that date, giving short notices of the genera and species which had been determined, as also their relationships to some of the recent and living forms. In this paper he also figured and described what he terms a new species of *Ascodictyon* from the Carboniferous limestone shales of Hairmyres, East Kilbride, and honoured the writer by naming it after him. I am very pleased to find that this new species agrees very closely in the form of its stem and its vesicles with those of a living form, *Valkeria tuberosa*, of Heller, which has been dredged in the Bay of Naples by Dr. Pergens. The resemblance between the recent and fossil forms is well shown in the illustrations given by Mr. Vine in the above-mentioned paper.*

In the foregoing remarks I have briefly indicated some of the earlier observations which led up to our present knowledge of the affinities or relationships of this obscure group of delicately-formed incrusting organisms found in palæozoic strata, and I shall now refer to another form of *Ascodictyon* which I have discovered, and which from its habit of growth seems to have lived under different conditions from those species already described. The latter are all incrusting, repent, forms upon the organisms to which they are attached, whereas both the stems and vesicles of the zoarium of the new form appear to have lived in an erect or free condition, like those of the recent genus *Valkeria*, already mentioned. The examples showing this new character were discovered when, in search of foraminifera and other microzoa, I was grinding down thin sections of the rich fossiliferous limestones from Trearne, Beith, and Laigh Baidland, Dalry. In some of the sections I detected, amongst the other organisms, fragments of narrow, thread-like stems having a polyzoan-like structure, and also numerous scattered vesicles of an elongated and pyriform shape, but for a long time they were a

* Plate IV., figs. 2, 3, and 4.

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complete puzzle, as I could not make out from the sections any relationship between the stems and the vesicles. After reading Mr. Vine's descriptions of *Ascodictyon*, and examining his figures of the recent *Valkeria*, I came to the conclusion that we had in these limestones evidence of the existence of a free-growing species of *Ascodictyon*, probably rooted at its base to some of the other organisms living on the same sea-bottom, but now scattered under fragmentary conditions amongst the other forms.

For further verification of this interesting point I sent two thin slides of the limestone to Mr. Vine, and also some chips so that he might prepare others for himself, and the following extracts from his letter of 8th May, 1892,—the last I ever received from him—show how pleased he was with my discovery. After acknowledging receipt of the slides, he says—"Now for the evidence afforded by the study of slide B. There can be no doubt whatever about the examples. You have afforded me evidence regarding the free condition of stems and vesicles long sought after, but never found in any of my examples. You will find in my paper, pp. 79 to 81, how tentatively I have dealt with recent and fossil ctenostomata. In the recent species of *Valkeria* the long filamentous thread or stem is free, and to this free thread a number of stellate clusters appear at intervals, with cells in all manner of dispositions, and, speaking generally, with cells of all sizes. The threads keep up a very close uniformity throughout as to size. This seems to be a very paramount feature in the ctenostomata wherever the vesicles are attached in whorls. I said above that in recent forms the threads are free."

"I will leave the Silurian forms for the present, and deal only with the evidence afforded by the study of your slide. In the first place, here are five descriptive examples out of many on the slide. In 1 we have a series of vesicles attached, but not in whorls, to a fine thread, one of which appears to be matured, or nearly so. In 2 is another stem with vesicles attached, nearly all the individuals being partly matured. In 3 the vesicles are apparently free, that is, as seen with a $\frac{1}{2}$-inch object glass, I cannot detect threads. In 4 are sections of threads without vesicles, very abundant on this slide; and in 5 is a thread with one cell, only, not in all cases, but in one at least, I find these clusters close to parts of the zoarium of *Fenestella* or *Glauconome*."

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"In the old Carboniferous sea of this Beith and Dalry district, these ctenostomatous polyzoa were evidently very abundant, and were basally rooted to some greater companions, while the stems or filaments were free, as free as the *Valkeria* and other ctenostomatous forms in our present seas. The same unkindly fate, (kindly in a geological sense) that overtook the host, perilled the life also of the 'parasite.' I suppose, the same that is 'doing' to-day in the envelopment of kindred forms, was 'doing' ages ago in these old limestone seas. What was 'doing'? you and others may ask—why, living forms of minute animals were extracting limy material from the surrounding 'pure' waters, and then, after their little span of life was lived, were being silently buried in the *debris* which they helped to create. I really believe that some of these Ascodictyons were thus buried even before maturity had time to show itself. But, otherwise, some of the many millions which must have served their day and generation fulfilled the purpose of their existence, and of these no record is left for us to ponder over. How gently Mother Nature must have covered with her slimy shroud these denizens of the deep we have ample evidence of in the material of this once chalky bed. Neither the foraminifera, the polyzoa, nor the other organisms have suffered the slightest abrasion in their long entombment. You think the vesicles were deciduous, and then fell off, and were thus buried. Well, when the cells were completely matured, that might have been the case, but as far as I can see, none of the unmatured cells have fallen off from the stems. These stems are now cleaned off in the grinding of the sections, but I believe all the cells are in the position which they occupied on the stem when living. Note, too, the uniform constancy in the diameter of the *Ascodictyon* stem wherever it is seen, and compare it with other stems on the slides. That itself is a study. I hope we shall hear more about this organism, for it well merits your very best attention."

Since Mr. Vine's death, I have, as opportunity permitted, continued the preparation of sections of all our fossiliferous limestones and shales which were likely to contain the remains of *Ascodictyon*, but in most instances, I find that this organism is entirely absent, or when present, that it is represented only by one or two scattered vesicles, or fragments of stems. Only in the limestones of Trearne, Beith, and Laigh Baidland, Dalry, have I

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found it as yet in anything like abundance, but in both these localities it seems to be confined to a thin stratum, which is characterised by a group of its near allies, the cyclostomatous polyzoa, such as *Fenestella, Glauconome, Polypora, and Rhabdomeson.* It is very probable, as suggested in Mr. Vine's letter, that in those tracts of the Carboniferous sea-bottom, the slender branching stems of the ctenostomatous polyzoa found a proper habitat, and were basally rooted upon the fronds and branches of more robust forms of the polyzoa. I may here mention that, rooted on some of the fronds of *Fenestella* from the Trearne limestone, I have found the remains of a slender branching organism, the stem of which is not unlike that of *Ascodictyon* in structure. Since the discovery of this form in the Ayrshire limestones, I have thought that, if not the basal portion of the stem of *Ascodictyon* itself, it may belong to some other form of the ctenostomata, although, as yet, I have not found any with vesicles attached to the branching stems.

The sections which I have prepared, some of which I exhibit to-night, clearly show that both stems and vesicles of *Ascodictyon* are now intimately mixed up with the other and smaller organic debris forming the limestone, and as the parts of *Ascodictyon* are so small as not to be visible to the unassisted eye, and are found lying in the matrix in all sorts of positions, and at all angles, it is very seldom that one finds, in thin transparent sections, any evidence of the vesicles being still attached to the slender thread-like stems on which they grew. This apparent detachment of the vesicles from the stems arises chiefly from the habit of growth of the organism, and from the varying way in which the vesicles lie in the matrix, relatively to the stems. We can, therefore, only guess what was its true form and habit of growth by carefully comparing its parts with those now seen in the nearest allied living forms.

In bringing to a close these few imperfect remarks upon this interesting occurrence of ctenostomatous polyzoa in Scottish limestone strata, I sincerely hope that further researches will enable future workers amongst the group to throw more light upon these somewhat obscure fossil forms, both in the way of pointing out the relationship of the stems and vesicles to each other, as well as in assisting the identification of other forms which still may be lying undetected in the different strata.

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No. XVIII.—On the Occurrence of Peat with Arctic Plants in Boulder-clay at Faskine, near Airdrie, Lanarkshire.

By James Bennie, of the Geological Survey of Scotland.

[Read 11th April, 1894.]

In a cutting into Boulder-clay at the brickwork at Faskine were exposed a number of peaty layers, to which, as giving a glimpse into the conditions of the glacial period different from what we get from ice-sheets and glaciers, I wish to direct the attention of the members of this Society, as having always been distinguished by the attention they have given to the study of glacial deposits.

Our knowledge of the occurrence of these peaty layers is due to Mr. Peter Jack, who first noticed them, and to Mr. Robert Dunlop, who brought me samples for examination, and who afterwards accompanied me on a visit I made to the spot, showed me the peat in place, and helped me to dig out further samples. Mr. Jack sent a large sample which he had dug out himself from a different layer than that from which the previous specimens were taken. I also made a special visit somewhat later, and took from the different patches as much material as I could get access to. All these various lots were afterwards washed and examined, with the result that many seeds, arctic plants, and mosses, were found. These were submitted to Mr. Clement Reid for examination, except the mosses, which were sent to Mr. Hobkirk. From Mr. Reid's list subjoined to this paper it will be seen that the plant-remains, chiefly leaves, belong to a species of Arctic Willow, *Salix herbacea*, which has been obtained in greater numbers from other old lake-deposits in Scotland. Mr. Reid considers that the presence of these Arctic Willows at the low levels where they are found proves the climate of Scotland to have been 20 degrees colder at the time they flourished than at present. This agrees with the circumstances in which the specimens were found, and gives the date of their existence as living plants to have been that of the later times and conditions of the glacial period.

The cutting from which the Faskine peat was obtained was made into the side of a very large Boulder-clay hillock, close by

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the old ironstone pit of Palace Craig, from which so many remains of Carboniferous reptiles were obtained some years ago. The chief of these, *Anthrasaurus Russelli*, has made Palace Craig famous, and its discoverer "immortal for the time being." The hard, dry shale heaps, being mixed with Boulder-clay, were ground down into a pasty mud for the purpose of making fire-bricks—the Boulder-clay being obtained from the above-mentioned cutting. This was about 100 feet in length, about 10 or 12 feet in breadth, and about 16 feet in depth. The peat was seen to lie in irregular patches, within about 4 feet of the bottom of the cutting. It was generally a peaty mud, loose in texture, and easily gouged out with a trowel or cut out with a knife. The patches were usually 1 to 2 inches in thickness, and 4 to 5 inches in breadth either way. Several of the patches consisted entirely of mosses, apparently of one species, closely wedged together as in their original habit of growth.

It was evident that these pieces of muddy peat and groups of mosses were not in the place where they had grown, nor where they had been deposited as sediment, but were waifs from some lake peat-bed, over which the Boulder-clay had been driven, when it had caught up portions and carried them along, as is clearly proved by their patchy and rounded form. But that they could not have been transported far was also evident from their purity, and freedom from any admixture with the Boulder-clay, and more especially from the fact that the mosses were in tufts as they had grown.

As the character of this peaty mud and its contents will be best seen from the notes made on the different samples as they were washed, I shall quote these almost *verbatim*, as follows :—

First sample, from Mr. Dunlop, 24th April, 1890.—Size about 6 inches by 4, and 1 inch in thickness. Compact, vegetable mud, much decayed, very black and fine in grain. Plants few, some mosses, and a few seeds. About a dozen bodies of water-mites, like black diamond dust; beetles in scraps, some highly coloured, like bits of tinsel paper. One layer of moss, washed separately, black and very spiky; seeds of *Hippuris* and *Carex*.

Second sample, from Mr. Dunlop, 20th May, 1890.—Great quantity of mosses, 80 or 90 per cent., some long, slender, and hair-like; others stumpy and spiky, very lycopod-like. Many

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leaves of *Salix herbacea*—same as from the fire-stone bed at Hailes, but better preserved; more seeds of *Carex*; spores of *Isoetes* frequent; innumerable minute black balls of solid carbon, supposed to be galls; one ostracod.

Third sample, taken when visiting Faskine with Mr. Dunlop, 31st May, 1890.—Face of Boulder-clay about 16 feet in depth, with peaty layers which were not continuous; Boulder-clay dividing them in patches. Tufts of mosses frequent in the peat, about 1 inch square. Results—great quantity of mosses, but not much variety; one kind with rod-like leaves or stalks; another thread-like, with several stems to one root. Also leaf-like bodies, lanceolate-like petals of flowers. Seeds more numerous, chiefly *Carex; Isoetes* common, but ruptured; beetles; water-mites like black pearls.

Fourth sample, sent by Mr. Jack, from 4 feet higher in the section.—On washing found it entirely wanted the mosses, and had only rootlets instead. Other things the same as in other samples; *Salix herbacea* numerous, often folded, appearing as half leaves; seeds few, chiefly *Carex;* spores of *Isoetes* plentiful; some animal remains like eggs or sacs. Sample from lower bed as before. *Salix* leaves in hundreds, folded; a few attached to stems which are small knotted twigs. Mosses in tufts in great profusion; sacs, and elytra of beetles, &c., scarce.

Fifth sample, taken at Faskine, 9th Sept., 1890.—Found Mr. Jack's upper bed by following thin lines of peat till they expanded into a series of peaty layers, extending 4 or 5 feet, sometimes only a thin parting, at other places 4 or 5 inches in thickness. Tried to "tirr" the Boulder-clay, but found I could not, as it was too tough and stony for my trowel to make any impression. Filled four bags with peat, which was all I could get.

The Boulder-clay rose 16 feet, and was hard, compact, and almost rock-like, and full of small stones, with one large trap boulder. Results better than before; leaves of *Salix herbacea*, two or three in every pinch; stems also in numbers with leaves attached; some stems intertwined like true lovers' knots; others tipped on top with small orbicular leaves studded with galls; spiky and feathery mosses in great numbers; animal remains, chiefly sacs, such as might have served as chrysalis cases, intensely black, thin-skinned, and traversed by a network of veins.

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The character of the peat and its contents, as given in these descriptive notes, seems to prove the existence near Faskine of a lake in which the remains of arctic plants, leaves, fruits, and stems were deposited during a time when the ice-sheet was temporarily lifted, so that plants could grow upon the land, and these water-mites and other creatures which live in water could exist for a time more or less lengthened, till the peat with all we now find in it was deposited under the lake-waters.

Further, the presence of the 16 feet of Boulder-clay in which the peat is now found as clearly proves a return of the ice-sheet with its concomitant drift, again overspreading the land and obliterating the free spaces in which the plants grew and the lakes existed, and burying up their remains in the great accumulation of stones and mud which it carried along with it or drove before it.

It is this occurrence of the Faskine peat *in Boulder-clay* which makes it remarkable—more remarkable than those of Hailes or Corstorphine, near Edinburgh—as these latter were clearly seen to lie upon or above the Boulder-clay, and to be overlain only by marls or ordinary lake sands, muds, and peats, so that they evidently belong to a later phase of the glacial period than the Faskine peat, with its 16 feet of Boulder-clay above it.

Both, however, must be reckoned as existing amongst the later times of the great glacial period, when the land vegetation consisted only of the Creeping Arctic Willow, and the mosses amongst which it crept and grew, and when our seas were inhabited by the Arctic *Tellina* and the *Pecten*, whose names have always been "familiar as household words" to the members of this Society.

List of Plants from Faskine Peat, determined by Clement Reid, F.L.S.

Viola palustris.
Stellaria.
Potentilla?
Hippuris vulgaris.
Salix herbacea.
Sedges—3 or 4 species.
Isoetes lacustris

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List of Mosses from Faskine Peat, determined by Charles P. Hobkirk, F.L.S.

Mollia inclinata, Hedw.
,, *tortuosa, L.*
,, *fragilis, L.*
Polytrichum commune, L.
Pogonatum alpinum, L.
Grimmia (sp?).
Racomitrium fasciculare, Schil.
Hypnum uncinatum, Hedw.
Climacium dendroides, L.
Amblystegium serpens, L.
Dicranum elongatum, Schp.
Blindia acuta, Dicks.

Mr. Hobkirk remarks that "except, perhaps, *Amblystegium serpens*, which grows chiefly in dry places, all these mosses are moisture-loving sub-alpine and alpine species more or less, and do not flourish in dry situations."

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PROCEEDINGS FOR SESSION 1892-1893.
(35TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 13TH OCTOBER, 1892.

Mr. JOHN YOUNG, F.G.S., *Vice-President*, in the Chair.

The CHAIRMAN, in opening the proceedings, congratulated the members present on the commencement of the work of another session, and expressed a hope that the high standard which the Society had reached would be not only maintained, but even extended.

Mr. JOHN SMITH, *V.P.*, read an interesting descriptive paper entitled "From the Doon to the Girvan Water along the Carrick Shore." [See page 1.] The paper was illustrated by a number of rock-specimens, and by diagrams and sections. At its close a discussion was taken part in by Messrs. John Young, F.G.S., Dunlop, and James Thomson, F.G.S., the latter stating that he hoped this wonderful tract of country would be taken up and worked out exhaustively by Mr. Smith, who, from his knowledge of North Ayrshire Geology, was so well qualified for the purpose. Mr. Murdoch said that a number of years ago he had seen in the hands of Sandy M'Callum, a well-known collector at Girvan, a number of specimens of Fossil Fish which he had got from the Old Red Sandstone beds at the Heads of Ayr.

Mr. JAMES NEILSON read "Some Remarks upon a Peculiar River-bed near Corrieburn." A stream here runs down the southern slope of the Campsie Fells, in an angle of rock formed by the sides and edges of sandstone strata tilted to about 45°, at a higher level than the rocks on either side of the channel. Some discussion followed, an opinion being expressed that the appearances noted might be the result of faulting from old workings. It was hoped that an excursion might be taken to the locality during next season, as Corrieburn was always attractive to the geologist.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH NOVEMBER, 1892.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read the Report of the Council for the preceding year (1891-1892). [See page 172.] The *Hon. Treasurer*

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(Mr. John Wight, C.A.) gave his Annual Financial Statement. [For an Abstract see page 177.] The *Hon. Librarian* (Mr. James White) submitted a Report on the affairs of the Library.

After some remarks by Mr. James Thomson, F.G.S., who objected that in the state of affairs no value was placed upon the Society's collection of specimens, the Chairman moved the adoption of the various reports—the motion being seconded by Dr. Ross and formally approved by the meeting. The Chairman then moved a cordial vote of thanks to the Hon. Secretary (Mr. Murdoch), Assistant Hon. Secretary (Mr. Pratt), Hon. Treasurer (Mr. Wight), and Hon. Librarian (Mr. White) for their work in the service of the Society, which was carried by acclamation.

As the names proposed for election were just sufficient to fill the vacancies occurring in the Council at this time, the following members were declared by the Chairman to be duly elected, without a ballot, to serve for three years:—as Vice-President, Mr. William Armour, C.E.; as Members of Council, Mr. John Young, F.G.S., Mr. James Anderson, Mr. John Main, F.G.S., and Mr. William Sinclair. As Auditors for the current year, Mr. David Pearson and Mr. John Boyd were elected.

The following gentlemen were elected Ordinary Members:—Mr. Hugh Caldwell, M.E., The Braes, Bridge of Allan; Mr. John R. M'Farlane, 22 Royal Exchange Square; Mr. William Miller, 3 Stanmore Terrace, Mount Florida.

Mr. JOHN KIRSOP exhibited various specimens as under:—(1) Large Photograph of a Fossil Tree found in a quarry at Clayton, near Bradford, Yorkshire; (2) a Boulder with Annelid Borings from the Smoo Cave, Durness, Sutherlandshire; (3) Spiegeleisen from Germany (used in steel manufacture); and some explanatory remarks were made by Mr. John Young, F.G.S.

Mr. DUGALD BELL exhibited a selection of rock-specimens, from a gravel and sand pit near Bridge of Weir, which showed a great variety of composition. They included Trap from the neighbouring Kilmalcolm range, and a considerable proportion of West Highland Rocks, which must have been transported from the north side of the Firth of Clyde.

Mr. JOHN YOUNG, F.G.S., read a short paper "On the Occurrence of Pyroxene or Augite, in Large Crystals, in Two Localities in Western Scotland." [See page 13.] The paper was illustrated by hand specimens and by sections prepared for the microscope. Some remarks upon the paper were made by Messrs. James Neilson, Cowie, and other members.

Mr. JAMES WHITE read "A Note upon the Occurrence of Sandstone 'Dikes' in California," in which he gave details of apparent "dikes," which to the eye and to the microscope appeared to be sandstone. The paper was illustrated by specimens of the rocks and photogravures of the "dikes." A considerable difference of opinion was expressed in the subsequent discussion by members, including Messrs. Young, Somerville, Neilson, Dr. Ross, and the Chairman, some of whom thought the so-called "dikes" must be the result of earthquake action causing fissures larger or smaller, which had afterwards been filled up by sand and water, the gradual

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consolidation of the particles giving the "dike"-like appearances now existing. [See a paper by J. S. Diller in the *Bulletin of the Geological Society of America*, vol. ii.].

SOCIETY'S ROOMS, 207 BATH STREET, 8TH DECEMBER, 1892.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

The following were elected members:—As Life Member, Mr. J. G. Sharp, 127 Great Hamilton street. As Ordinary Members—(1) Ex-Bailie James Blackwood, Kilmarnock; (2) Mr. John Arthur Brown, Dowanhill Gardens; (3) Mr. W. P. Buchan, Fairyknowe, Cambuslang; (4) Mr. Hugh D. Lusk, Rosebank, Forsyth street, Greenock; (5) Mr. John M'Glashan, Woodneuk, Gartcosh.

The CHAIRMAN announced that the Council had unanimously agreed to elect Mr. James S. M'Lennan a Member of Council to fill the vacancy caused by the death of Mr. D. C. Glen, F.G.S.

The HON. SECRETARY (Mr. Murdoch) read a note "On the Life and Work of the late Mr. David Corse Glen, F.G.S.," since 1866 one of the Society's most active working members. His remarks were supplemented by Mr. John Young, F.G.S., who proposed a vote of condolence with the family of the deceased gentleman. This was seconded by Dr. Forster-Heddle, F.G.S., and unanimously agreed to. [This note will be printed in the next part of the *Transactions*.]

Mr. ROBERT DUNLOP exhibited a fine specimen of *Ulodendron*, with many scars, and as usual much flattened, from the oil shale of West Calder, and some remarks on it were made by Mr. John Young, F.G.S.

Dr. FORSTER-HEDDLE, F.G.S., exhibited a specimen of a Serpentine Boulder from Balhamie Hill, South Ayrshire, and stated that it was one of the most remarkable Scottish serpentines which had ever come under his notice. He had hopes of being able to trace it to the rock *in situ*.

The HON. SECRETARY (Mr. Murdoch) exhibited a number of Photographs of Geological Sections, presented to the Society's Collection by Mr. Robert Dunlop and Mr. Alexander Drew.

Mr. DUGALD BELL, F.G.S., read a paper "On the Origin of certain Granite Boulders in the Clyde Valley." [See page 16.] The author's remarks were illustrated by Nicol's and Geikie's Geological Maps of Scotland. At its close some discussion was taken part in by members, the speakers generally agreeing with Mr. Bell in the theory he had advanced. Mr. John Young, F.G.S., stated that most of the granite boulders found in the excavations made for the foundations of the New University Buildings at Gilmourhill were of the same type as the boulders described by Mr. Bell. About 25 years ago a Captain Littlejohn had brought some similar specimens from the Arrochar hills, which were now in the Hunterian Museum. Dr. Heddle complimented Mr. Bell upon his paper as being the model of what such a paper should be—calm, logical, and dignified. If the rock-specimens were supplied he thought he might

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speak for Bailie Blackwood as well as himself, and say that they might jointly contribute one or two interesting papers on them to the Society's *Transactions*.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH JANUARY, 1893.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

Mr. R. M. Hogg, Teacher, Irvine, was elected an Ordinary Member.

Mr. JAMES NEILSON moved "That the Council be empowered to hand over to the Kelvingrove Museum, or such other public body as would undertake to keep it on exhibition, the Society's Collection of Rocks, Minerals, and Fossils." After some discussion further consideration of the motion was adjourned till next meeting.

Mr. JOSEPH SOMMERVILLE exhibited, with remarks, specimens of several Rare Minerals from North America, including Wulfenite, a Molybdate of Lead; Tourmaline, variety Rubellite; Felspar, variety Perthite; a beautiful specimen of Chrysotile—popularly called Asbestos—and a specimen of Mica, with Magnetite in thin plates, through which light could be transmitted, contrary to the usually accepted theory that light could not be transmitted through this mineral.

Mr. JOHN YOUNG, F.G.S., exhibited, on behalf of Mr. John Kirsop, specimens of Kauri Gum, a sub-fossil resin, from New Zealand; also Magnetic Sand from the same country, and made some remarks upon their occurrence and distribution.

The CHAIRMAN (Mr. John Smith, *V.P.*) read a paper "On a Section of Carboniferous Strata near Giffen Station, Ayrshire." [See page 25.] The paper was illustrated by sections, and by specimens of the various strata exposed in the railway cutting. In the subsequent discussion, taken part in by Messrs. John Young, F.G.S., Thomson, F.G.S., Blackwood, Bell, F.G.S., and others, it was thought that the locality might be visited in one of the Society's excursions in the course of next spring.

Mr. JOHN YOUNG, F.G.S., read a biographical notice of the late Mr. James Armstrong, an original member of the Society, and for many years one of its most energetic workers. He had contributed many papers to the *Transactions*, besides acting as Secretary and as Librarian for a number of years. Several of the older members, including Messrs. Richard Neilson, James Thomson, and the Hon. Secretary (Mr. Murdoch), spoke of their long acquaintance with Mr. Armstrong, and of their regret at his sudden death in the United States of America. A vote of condolence with the family was then proposed by Mr. Young, seconded by Mr. Dugald Bell, and unanimously agreed to. In connection with this matter Mr. R. Dunlop suggested that on the occasion of the loss of outstanding members their portraits might be given in the *Transactions*. [For this and other biographical notices see the next part].

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SOCIETY'S ROOMS, 207 BATH STREET, 9TH FEBRUARY, 1893.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

The discussion upon Mr. Neilson's motion regarding the Society's Collection of Specimens adjourned from the previous meeting was taken up. An amendment, "That cases to contain the type specimens in the collection should be purchased and arranged for exhibition and use in the Society's Rooms," was moved by Mr. James Thomson, F.G.S. It was ultimately agreed that the whole matter be remitted to the Council for consideration and report.

The CHAIRMAN spoke in feeling terms of the catastrophe which had lately befallen a kindred society south of the Tweed—The Philosophical and Literary Institute of Newcastle—the whole of its extensive and valuable library and its other collections having been destroyed by fire. It was agreed that the Secretary should send a letter of sympathy and offer to replace the *Transactions* of this Society, the previous set having doubtless undergone the fate of the rest of the books.

Mr. DUGALD BELL, F.G.S., exhibited specimens of Fossil Shells from the Upper Coal Measures near Holytown, which had been lately sent to him under the impression that they might belong to the same shell-bed as that said to exist at Chapelhall. The present specimens were true Carboniferous fossils, whereas these noted from Chapelhall were Arctic shells, thus being of comparatively recent date. Mr. Bell spoke of the great caution necessary in accepting reports of the existence of shell-beds without full examination of all points connected with them. He then referred to the question which had arisen in late years regarding some of the high-level Post-tertiary shell-beds being *in situ*, that term being, of course, used by all geologists to express the fact that such beds were in their original position as laid down by the sea, and as not having been moved subsequently by ice or some other agency. He quoted leading geologists to show that such doubts had been expressed specifically with regard to Chapelhall, and that, therefore, it was beside the mark to characterise by strong terms doubts now expressed on the question. Such matters were not to be decided by mere statements that certain shells had been seen in a certain position or in a certain person's possession, but only by exhaustive examination of the surrounding clay and its contents, such as, till a few years ago, was not even dreamt of.

Mr. JAMES THOMSON, F.G.S., exhibited a photograph and a cast of a specimen of *Astarte borealis*, said to have been recently got in the neighbourhood of Chapelhall, and therefore indicating the existence of other arctic shell-beds in that locality than the Chapelhall one. Mr. James Steel and other members expressed doubts as to the correct identification of the specimen, so far as shown by the photograph and cast, and thought it rather resembled *Venus gallina*, a recent shell.

Mr. JOHN SMITH, *V.P.*, read a paper on "The Geological Position of the Irvine Whale Bed." [See page 29.] The paper was illustrated by a number of coloured sections and by specimens of shells and rocks from the various deposits.

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SPECIAL MEETING.

SOCIETY'S ROOMS, 207 BATH STREET, 23RD FEBRUARY, 1893.

Mr. WILLIAM JOLLY, F.G.S., *Vice-President*, in the Chair.

Dr. FORSTER-HEDDLE read a paper upon "Agates, Chalcedonic and Zeolitic Druses." The author, who was introduced by the Chairman as *facile princeps* in his subject, described agates as representing vapour-vesicles in igneous rocks, which, after partial alteration of the latter, have been more or less completely filled by the deposition of decomposition-products of the several minerals composing the rocks. He then described in detail the various kinds of agates—their structure and formation. The paper was illustrated by eighteen diagrams, twelve of which were in colours. On its conclusion a hearty vote of thanks was awarded to Dr. Heddle for his kindness in coming to address the Society.

[This paper will be given in the next part of the *Transactions*.]

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MARCH, 1893.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

Mr. W. P. Buchan, Fairyknowe, Cambuslang, was elected a Life Member; and Mr. William Steele, 12 Wendover Crescent, Mount Florida, was elected an Ordinary Member.

Mr. JAMES STEEL exhibited specimens of *Astarte borealis*, from a Post-tertiary shell-bed near Greenock, and of *Venus gallina*, from a recent beach deposit, in order to show that it was a photograph and cast of the latter shell which had been exhibited at the previous meeting. The occurrence of *Venus gallina* at Chapelhall could only be accidental, and, therefore, of no bearing upon the question as to the existence of an arctic shell-bed there. A subsequent discussion was taken part in by Messrs. James Thomson, F.G.S., Dugald Bell, F.G.S., Dunlop, Murdoch, Sommerville, and other members.

Mr. JOHN YOUNG, F.G.S., read, on behalf of Mr. Thomas Steel, F.C.S., Yarraville, Australia, and late of Greenock, a paper entitled, "On Australian Coals." [See page 51.] The paper was accompanied by numerous illustrative specimens which the author had presented to the Hunterian Museum. At its close remarks were made by Messrs. James Thomson, F.G.S., James Steel, and other members.

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Mr. John Smith, *V.P.*, a paper "On an Alleged Bed of Shells at High Molmont, near Galston, between 400 and 500 feet above sea-level." [See page 58.] Some discussion followed, being taken part in by Messrs. Young, Bell, Thomson, and W. J. Millar. A hope was expressed that Mr. Smith would follow up his investigations at High Molmont, and report the results on a future occasion.

Mr. JAMES NEILSON read a paper "On the Calderwood Limestone and Cementstone, with their Associated Shales." [See page 61.] The paper was illustrated by a large series of specimens from the author's collection, many

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being very fine and rare, if not unique. A short discussion was taken part in by Messrs. John Young, F.G.S., Steel, Reid, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH APRIL, 1893.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

Before beginning the regular business of the meeting, the CHAIRMAN briefly referred to the honour which had just been paid by the University of Glasgow to the Society's old and worthy member, Mr. John Young, F.G.S., by conferring upon him the degree of Doctor of Laws (LL.D.). Several members also remarked upon the occasion, and the meeting received the announcement with much enthusiasm. Dr. Young briefly responded, expressing his acknowledgments for all the good wishes he had been offered.

Mr. Thomas Steel, F.C.S., Yarraville, Australia, was elected a Corresponding Member,

Mr. ROBERT DUNLOP exhibited a remarkable specimen of Limestone from a bed lying above the Ayrshire upper coal, submitting an analysis and a microscopic section, and making some remarks upon its occurrence. It showed a curious banded appearance, but apparently did not contain any fossils by which it might be correlated.

The CHAIRMAN (Mr. Smith) exhibited—(1) A specimen and microscopical section of Amygdaloidal Burnt Coal from Crosshouse. This Burnt Coal is a seam which has lost its volatile matter from being in contact with trap rock. Some parts are beautifully columnar, and where this is the case the amygdaloidal structure has not been developed, no doubt owing to the gases and steam having passed off from the coal along the divisional planes of the columns. Where the columnar structure is very faintly developed, or not at all, the amygdaloidal structure is best seen, and though a good deal dispersed through that part of the seam, still it is best developed in certain bands parallel with the original bedding of the coal. The amygaloidal cavities run up to ⅛ inch in diameter, are very unequal in shape, and have often pointed ends. They are filled with calcite with highly polished surfaces from contact with the original polish of the cavities. After weathering they become brownish from oxidization, but still retain their polish. The coal has also bands and streaks filled with calcite.

(2) A specimen of *Aporrhais pes-pelicani*, or Pelican-foot shell, said to have been found at Lugar in a pit 600 feet above sea-level. Mr. Smith said he had possessed this shell for about twelve years, always expecting to get some more information about it. Not having found it himself, nor even having got it from the person who did find it, he had not succeeded in getting any further particulars. It is evidently a fossil, and has been preserved in dark mud. The species has been found in Scotland in four glacial-bed localities, at Gourock, Kilchattan, &c.

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(3) A specimen of what might be described as "Nature-polished" Stones, from the Irvine Water, near Shewalton. At a point in the bed of the river at Shewalton a little iron-charged stream enters it, and for some distance downwards the stones in the bed of the river are highly polished. After a time the hydrated oxide is deposited, but the tops of the boulders, which stand well up in the water, still retain the polish, which appears to be a result of chemical action. As the Society visits this locality in the excursion arranged for the 5th of August, the members may have an opportunity of inspecting these polished stones if the water in the river is sufficiently low at the time.

Mr. JOSHUA BUCHANAN read a paper on "The Mining Industries of Chile," in which he reviewed, from personal experience, the various processes adopted in that country for the extraction and recovery of nitrate of soda, gold, silver, and copper. He then exhibited by means of the oxy-hydrogen lantern, and with a running commentary, a large series of photographs, which had been taken by himself during his residence, many of them of great beauty and interest.

The HON. SECRETARY (Mr. Murdoch) then made a few remarks upon a small series of Norwegian slides thrown upon the screen, principally of the Buerbrae Glacier, near Odde, on the Hardanger Fjord, which he had visited in 1888.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH MAY, 1893.

Mr. WILLIAM JOLLY, F.A.S., in the Chair.

Mr. A. HUMBOLDT SEXTON, Professor of Metallurgy in the Technical College, was elected an Ordinary Member.

Mr. J. R. M'FARLANE exhibited a number of specimens of Fossil Fish from the Old Red Sandstone of Caithness, regarding which Dr. John Young, F.G.S., made some explanatory remarks. [Dr. Traquair named these fish at a subsequent meeting. See page 169.]

Professor M. Forster-Heddle, St. Andrews, read a paper "On the Occurrence of Tachylyte at Loch Screden, Mull," a new Scottish locality for this rare substance, which the author described as "the black bottle-glass-like selvage occasionally found upon the contact surfaces of basaltic dykes." [See page 80.] The paper was illustrated by numerous drawings, made by the author on the blackboard with coloured chalks. An interesting discussion followed, being taken part in by several members.

Mr. JOHN RENWICK read a paper entitled "Notes on an Excursion to Glen Fruin, with a Description of the Moraine on its South Side. [See page 96.] The paper was illustrated by a map of the district, and by photographs taken by Mr. William Sinclair. A discussion followed, being taken part in by Mr. Dugald Bell, F.G.S., who dissented from the author's views regarding the direction of the ice-flow which had produced the moraine, and by other members.

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SOCIETY'S ROOMS, 207 BATH STREET, 24TH MAY, 1893.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

Mr. James Thomson, F.G.S., was elected an Honorary Member of the Society. Mr. Peter Innes, 5 Ibrox Place, Paisley Road; Mr. William A. M'Innes, 20 Dixon Avenue, Govanhill; Mr. Matthew Gemmell, 75 Bath Street; and Mr. John Donnachie, 57 Hope Street, were elected Ordinary Members.

Dr. JOHN YOUNG, F.G.S., exhibited, on behalf of Mr. John Kirsop, a specimen of Rock Crystal enclosing a perfectly formed Crystal of Iron Pyrites, a circumstance of very rare occurrence.

Mr. DUGALD BELL, F.G.S., read a paper "On the Alleged Proofs of Submergence in Scotland during the Glacial Epoch—II., Clava, and other Northern Localities. [See page 105.] A subsequent discussion was taken part in by Mr. William Jolly, F.G.S., and other members.

Mr. JOSEPH SOMMERVILLE exhibited a specimen from a bed of clayband ironstone now being worked at No. 4 pit, Garscube, which showed "Cone-in-cone" structure. Above and below the ironstone band there was a layer of calcareous material, and in each layer "Cone-in-cone" was well developed, having the apices of the cones in both cases pointing towards and resting upon the ironstone in the centre of the mass, and thus pointing in opposite directions. Mr. Sommerville said that these appearances were not explainable by Dr. Young's theory [see *Transactions*, Vol. viii., page 1] as to the formation of this curious structure. An animated discussion on the specimen was taken part in by a number of the members, but owing to the lateness of the hour it had to be adjourned.

The Chairman then declared the 35th session to be closed and expressed the hope that the members would all meet for another session in October next.

PROCEEDINGS FOR SESSION 1893-94.

(36TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 12TH OCTOBER, 1893.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

Mr. SOMMERVILLE asked permission to call attention to the number of members who had been removed by death since the last meeting (in May), including Sir Michael Connal, Dr. Crosskey, Bailie Blackwood of Kilmarnock, Mr. Thomas Naismith, and Mr. R. R. Horne, and suggested that short notices of the deceased gentlemen should be read at an early meeting.

Mr. ROBERT DUNLOP exhibited specimens of Serpentine from Lendalfoot, on the Ayrshire coast, and made some remarks upon its origin and occurrence.

Mr. James B. MURDOCH, *Hon. Secretary*, also showed specimens of Serpentine from Portsoy, Banffshire, where it is largely developed, being at one time worked for industrial purposes.

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Mr. JOHN SMITH, *V.P.*, showed a Quartzite Boulder, showing structure, possibly perlitic, and a short discussion upon such structure in rocks followed, being taken part in by Dr. John Young, F.G.S., Mr. Robert Kidston, F.G.S., Mr. James Neilson, and other members.

Mr. JAMES NEILSON showed several Quartzite Pebbles from Little Cumbrae, on the surface of which he thought he had discovered fossil remains. After more careful examination, he had since come to the conclusion that these markings were alterations of structure, due probably to percussion.

Dr. JOHN YOUNG, F.G.S., exhibited specimens of a White Vein-Quartz, enveloping crystallized calcite of a deep, reddish-brown colour. This is the Hæmatoconite of Hausman, a variety of red calcite seen in the Italian marble, "rosso antico." The specimens exhibited were found on the Corrie shore, Arran, during last autumn, by Dr. Thomas Young, of Manchester, and were presented by him to the Hunterian Museum. They formed part of a small boulder, the great contrast in colour between the pure white of the quartz and the red of the calcite giving the rock a striking and handsome appearance. Such colour appears to be rare in Scottish calcite.

Mr. JOHN SMITH, *V.P.*, read a short paper "On a Bed of Fossil Plants, and one of Limestone with Magnesia, in the Calciferous Sandstone Series at Meikle Busbie, near Ardrossan." [See page 129.] The paper was illustrated by a section, and by a number of specimens of the rocks referred to.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH NOVEMBER, 1893.

ANNUAL GENERAL BUSINESS MEETING.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

The HON. SECRETARY (Mr. Murdoch) read the Report of the Council for the past year. [See page 174.]

The HON. TREASURER (Mr. John Wight, C.A.) submitted his Annual Financial Statement. [For an Abstract see page 178.]

The HON. LIBRARIAN (Mr. James White) gave his Report on the work of the Library during the year.

These various reports were considered to be satisfactory, and, on being put by the Chairman to the meeting, were unanimously approved.

A hearty vote of thanks was then awarded to the Hon. Secretary (Mr. Murdoch), Assistant Hon. Secretary (Mr. Pratt), Hon. Treasurer (Mr. Wight), and Hon. Librarian (Mr. White), for the unstinted work they had done in the cause of the Society.

The vacancies occurring amongst the office-bearers at this time were then filled by the election of Sir Archd. Geikie, Bart., as President; Mr. John Dansken, F.S.I., as Vice-President; Messrs. Matthew Blair, Robert Dunlop, William Jolly, F.G.S., and James Neilson, as members of Council, all for three years. Mr. James Barclay Murdoch was re-elected Hon. Secretary; Mr. Gavin M. Pratt, Assistant Hon. Secretary; Mr. John

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Wight, C.A., Hon. Treasurer; Mr. James White, Hon. Librarian; all for a term of three years. Messrs. John Boyd and David Pearson were reappointed Auditors for the current year.

The CHAIRMAN proposed a hearty vote of thanks to Lord Kelvin, the retiring President, for his long-continued services to the Society, and this was warmly approved of.

Mr. Patrick Barr, 57 Bath Street; Mr. Walter Dixon, E.E., 164 St. Vincent Street; Mr. Thomas Frank Glen, 14 Annfield place, Dennistoun; Mr. George M'Crie, 61 Cecil Street, Hillhead; and Mr. Henry Taylor, 20 Campbell Street, Maryhill, were elected Ordinary Members.

Mr. C. L. DOBBIE presented to the members a handsomely framed, life-size photographic Portrait of the late Mr. D. C. Glen, F.G.S., so long a member and an office-bearer of the Society, and the gift was cordially accepted by the Chairman.

Short notices of lately deceased members of the Society were read as follows:—Sir Michael Connal, by the Hon. Secretary (Mr. Murdoch); Rev. Dr. Crosskey, by Dr. David Robertson; Bailie Blackwood of Kilmarnock, by Dr. Forster-Heddle; Mr. Thomas Naismith, by Mr. James Neilson; Mr. R. R. Horne and Rev. Canon Mackintosh, by the Honorary Secretary. [For these obituary notices see the next part of the *Transactions*.]

Mr. James S. M'Lennan read a paper entitled "A Ramble up the Maich Water, Ayrshire." [See page 121.] A short discussion followed.

SOCIETY'S ROOM, 204 BATH STREET, 14TH DECEMBER, 1893.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

Mr. Robert Brown, 17 Oswald street, was elected an Ordinary Member.

The HON. SECRETARY read a letter he had received from Sir Archibald Geikie, Bart., thanking the members for the honour they had done him in electing him to the Presidentship, and hoping that he would be able to pay the Society at least an occasional visit.

Mr. MATTHEW BLAIR moved "That it be remitted to the Council to consider what steps can be taken to render the proceedings of the Society more educative and attractive to new members." After Mr. Blair, a number of the other members spoke on the subject, including the seconder, Mr. R. J. Steele, the Hon. Secretary (Mr. Murdoch), Messrs. Steel, Sommerville, Macintosh, Neilson, Dunlop, Dr. John Young, and the Chairman. Ultimately the matter was, in the terms of the motion, "remitted to the Council to consider" and report.

Mr. JAMES NEILSON moved "That £8 of the Society's Funds be devoted to the purchase of new books during this session." The Chairman suggested that the sum should be altered to £10, which Mr. Neilson agreed to, and which became the finding of the meeting.

Mr. JOHN SMITH, *V.P.*, exhibited, with remarks, some interesting specimens sent from Umtale, South Africa, by Mr. Edward Carrick,

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Inspector of Mining Claims, including Bluestone, Silicified Wood, Gold bearing Quartz, Alluvial Gold, Reef Gold, Crocoisite (Mono-chromate of Lead) and Arragonite. Dr. John Young, F.G.S., also spoke upon points connected with the specimens, especially as to the origin and presence of gold in igneous and volcanic rocks, stating that it has probably been brought from great depths in connection with highly heated waters strongly charged with silica.

Mr. Smith also exhibited a specimen of *Megalichthys pygmæus*, from Airdrie, and a number of Fossil Shells from Ayrshire, none of which were recorded in the "Catalogue of Western Scotland Fossils," and remarks were made upon the specimens by Messrs. James Steel, Robert Dunlop, and other members.

Mr. JOHN SMITH read a paper "On a Bed of Ironstone occurring in Trap Tuff in the parishes of Stevenston, Dalry, and Kilwinning, Ayrshire. [See page 133.] The paper was illustrated by a number of specimens from the ironstone and adjacent beds, which were afterwards presented by the author to Dr. Young, for the Hunterian Museum. An interesting discussion followed, remarks being made by Mr. James S. M'Lennan, Mr. James Neilson, Dr. Young, and the Chairman.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH JANUARY, 1894.

Mr. WILLIAM ARMOUR, C.E., *Vice-president*, in the Chair.

The following gentlemen were elected members. As Life Members:—Prof. Archibald Barr, C.E., Royston, Dowanhill; Mr. James Barr, C.E., 221 West George Street; Mr. Robert Bryden, F.R.I.B.A., 212 St. Vincent Street; Mr. Robert A. M'Gillvray, 129 West Regent Street; Mr. Robert Murdoch, 19 Commerce Street; Mr. George Barlas, 15 Ruthven Street, Kelvinside; and Mr. William Gilfillan, 129 St. Vincent Street. As Ordinary Members:—Mr. John James Burnet, A.R.S.A., 18 University Avenue; Mr. Alexander Frew, C.E., 175 Hope Street; Mr. John James Hubbard, 25 Lilybank Gardens, Hillhead; Mr. Walter Raglan Hubbard, 9 Broomhill Avenue, Partick; Mr. Alexander M'Ara, 27 India Street; Mr. Thomas Ogilvie Niven, C.E., 131 West Regent Street; and Mr. Andrew Ross, 12 Ann Street.

Dr. JOHN YOUNG, F.G.S., exhibited on behalf of Mr. Robert Kidston, F.G.S., microscopic sections of Quartzite and Pitchstone, shewing perlitic structure. This structure consists of a series of hair-like crystals, which, when most perfectly developed, assume circular or curved lines, or even become complete circles.

Dr. Young also exhibited, on behalf of Mr. James Neilson, a number of specimens, including:—Quartzite Pebbles, showing alteration of structure through percussion; Serpentine from Portsoy, &c.

The HON. SECRETARY (Mr. Murdoch) exhibited, on behalf of Mr. John Smith, specimens of Serpentine from the Boulder-clay near Lendalfoot, Ayrshire, and read some notes by Dr. Forster-Heddle on the occurrence in

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Ayrshire of this particular variety of the mineral. The find is of considerable interest, as serpentine, with veins of chrysotile, crystals of pseudo-enstatite, and precious serpentine, all of which are contained in Mr. Smith's specimen, has only been known previously to occur in Scotland at Colafirth, in Shetland. Its presence in the Ayrshire Boulder-clay seems to indicate that it may be found at no great distance *in situ* from the same locality.

Dr. JOHN YOUNG, F.G.S., exhibited several specimens, as follows:—

1. Pearlstone, which belongs to the pitchstone group of the felspars, has a pearly lustre, and is sometimes found in small spherules, as in spherulite.
2. Uraninite or Protoxide of Uranium, from Perth, Western Australia. This mineral is of much value in the painting of porcelain, as it yields an orange colour in the enamelling fire, and a black colour in the baking furnace.
3. A new species of Sigillaria found by himself, in 1864, during the sinking of a pit to the Possil ironstone at Robroyston, north-east of Glasgow. This species had been recently described by Mr. Robert Kidston, F.G.S., in a paper to the Royal Physical Society of Edinburgh, as being the first British example of the Ribbed Sigillaria which had been found in strata older than the millstone grit series. Mr. Kidston had named it, after its discoverer, *Sigillaria Youngiana*, its provisional name having been *S contracta*, Brongt.

Mr. JOSEPH SOMERVILLE exhibited, with remarks, specimens of Magnesian Limestone, with Oolitic Structure, from Somersetshire—the stone of which St. Paul's Cathedral is built—also specimens of Magnesian or Dolomitic Limestone from Roker, near Sunderland, on the coast of Durham. Dr. Young and other members took part in the subsequent discussion on the structure of these limestones.

The HON. SECRETARY (Mr. Murdoch) exhibited several specimens of Quartzite showing alteration of structure and occasional evidence of bulbs of percussion from river action.

Mr. MURDOCH read, on behalf of Mr. John Smith, a paper "On a Mineral in a Fumerole at Auchenharvie Castle, Kilwinning." [See page 137.] The paper was illustrated by sectional drawings, specimens of the rocks, and microscopic sections.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH FEBRUARY, 1894.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

The CHAIRMAN (Mr. Smith) exhibited a number of specimens, with remarks, as under:—

1. Dendritic Pyrites from Fergushill Ha', Kilwinning. The dendritic markings on the specimen (a fragment of what it once was) extend to the length of 1½ inches. The pyrites has been deposited in a joint of the trap, on a thin skin of what is probably cluthalite.

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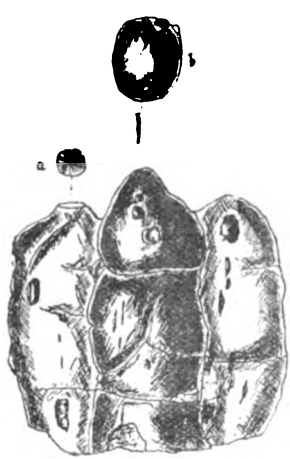
Mr. Smith said that he had not previously met with a similar arrangement of the markings.

2. *Lithodendron junceum*, converted into pyrites, from Cleaves Glen, Dalry. It occurred in a nodule in shale lying below the lower bed of limestone. The septa and tabulæ have been but faintly preserved, and it is only the wall of the coral which, as a rule, has been fully converted into pyrites. It is the first specimen of a coral so altered which Mr. Smith had met with.
3. *Anthracosia robusta*, found in its living position in the Dalmellington ironstone. When visiting the district Mr. Smith saw several specimens of this shell in the blackband ironstone, and all upright. At the present day *Anodonta* lives in a similar position in river mud, hybernating during winter, and on one occasion he took 60 specimens in this condition from the Dusk Water, near Dalry, in about two square yards.
4. Large Spherulites, from Dun Fion, Arran. For the previous 15 years Mr. Smith had known that spherulites occurred in this locality in a detached condition, but had never been able to find the bed itself. For the specimens exhibited he had been indebted to the rabbit burrows on the hill-slope above the farmhouse of Dun Fion, beside the thick beds of pitchstone at that place. The largest spherule is 2¾ inches long by 1¼ inch wide. It is soldered by its sides to two smaller ones, and has been longer than it now is to the extent of, perhaps, 1½ inch. Most of the spherulites show constrictions and warts, and slight ridges occur here and there on their surfaces. They have a radiate structure, and their surfaces, where well weathered, show a pitted appearance, almost identical with the coral, *Chætetes tumidus*. It is very seldom that any of the rock with the spherules in position is to be got, and then it is very much decomposed. The smallest spherule found measures ⅞ inch long by ⅝ inch in breadth, and a little less in thickness. It is quite complete.



5. Dark-grey Vitreous-looking Sandstone Veins ramifying through trap, from the Baths, Ardrossan. In the "Explanation" to sheet 14 of the Geological Survey, cavities in the trap of the Maybole and Kirkoswald coast, filled with very fine-grained sandstone, are described, and in America "dikes" of sandstone, cutting for miles through sedimentary *(Cretaceous)* strata, have been found.

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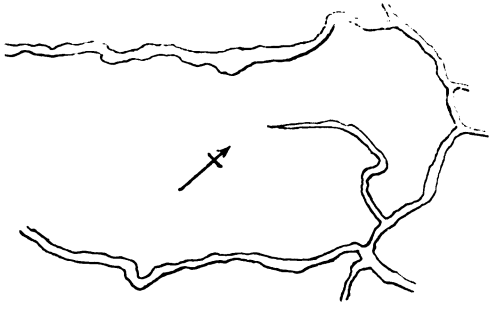
The Ardrossan trap is evidently intrusive, the sandstone above it being considerably hardened. The veins in the trap come right up against this sandstone, being placed mostly in a vertical direction, but possibly never exactly so. They ramify in all



directions, and are from less than an inch up to 9 inches in thickness, though the last-named width is exceptional. The sandstone is composed in great part of quartz grains, mostly angular, and a few mica scales, with some felspar and magnetite. Not many of the grains are more than $\frac{1}{100}$ inch in diameter. Close on the trap the mica scales lie flat against it, but farther out at various angles. The sandstone veins show towards their sides faint traces of stratification, the bedding planes being parallel to the sides of the veins. How the trap has become rent as it is, and where the infilling sand came from, are questions Mr. Smith was not prepared to answer. If not quite cooled down the trap must have been at least somewhat solid when it was rent, as angular fragments of it are embedded in the sand veins.

Dr. SAMUEL SLOAN exhibited a large Photograph, taken by himself, of "The Witches' Rock" in Glen Tilt, and gave an account of his latest visit, when he was able, for the first time, to photograph the rock in twilight, showing a number of weird and fantastic shadow forms, the occasional appearances of which to the passer-by, probably gave rise to the local name.

Mr. JAMES NEILSON exhibited a series of fresh-water shells from Carboniferous strata, *Anthracosia*, *Anthracomya*, and *Anthracoptera*, and gave some particulars of their probable occurrence in the beds where they are found.

Mr. Neilson also showed, with remarks, a Collection of Marine Shells from the Upper Coal Measures, which had been formed by the late Mr. R. A. Skipsey, long an active member of the Society, and which had been referred to in volume ii. of the *Transactions*.

Dr. JOHN YOUNG, F.G.S., read a paper "On the Protoconch of *Orthoceras*, and on the evidence of its Remains in certain Scottish Carboniferous species, with illustrative specimens." [See page 139.] The paper was illustrated by specimens belonging to several different species.

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SOCIETY'S ROOMS, 207 BATH STREET, 8TH MARCH, 1894.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

Mr. James Neilson, 116 Bishop Street, Port-Dundas, was elected a Life Member; Messrs. James Maclay, 169 West George Street, and D. Macnaughton, 137 West Regent Street, were elected Ordinary Members.

Mr. JOHN SMITH, *F.P.*, exhibited a number of specimens, as follows:—

1. Brecciated Greywacke from Lendalfoot Burn, Ayrshire. This rock appeared to have been brecciated from a mass which had been very much twisted before being broken up. The fragments are cemented by white crystalline calcite, the peculiar feature being the large amount of the latter present, the rock-fragments not having been crushed very closely together. The specimen exhibited, which is a pebble from the Boulder-clay, has come from the moorland district between Barr and Dailly in Ayrshire, where a great deal of the brecciated rock can be seen.
2. Brecciated Spherulite from the Kilbirnie Hills. This specimen was found as a pebble in the bed of a small stream. The spherulitic fragments (a few of the spherules are complete) are whitish towards the centre, and pale red towards the edges. They are cemented by granular reddish silica, and contain a few minute reddish crystals of felspar. Probably the rock *in situ* is not far distant from the spot where the specimen was found, as there is little indication of Boulder-clay so far up.
3. Rock Fragments from near the centre of the Arran granitic area, a little to the east of Loch na Davie. These fragments naturally divide themselves into four varieties—(*a*) specimens striated like a cornice moulding; (*b*) prismatic specimens, the prisms being about ¾ inch in diameter, and compressed; (*c*) specimens made up of a number of compressed irregular cylinders closely compacted together; (*d*) a mass of polygonal tubes of a light colour with dividing tabulæ, and filled with a very fine-grained material of a darker colour. The walls of the tubes and the infilling material are highly silicious, and strike fire with steel. Specimens of the (*a*) type have been moulded on the slickensided face or faces of a fault in the granite, but as to the formation of the others Mr. Smith offered no opinion.
4. China Clay from the Schrevin Clun Shaune, Arran. Dr. Bryce describes the China Clay of Arran as occurring in thick beds, but this is misleading, it having resulted from the decomposition of fine-grained granite *in situ*. The east side of Meol Biorach Hill, towards the top of Catacol Glen, has at one time been crushed into a mass of fragments, few of which are larger than one's hand, the better preserved ones being striated. This brecciation of the rock has allowed the water to get in more freely amongst it, and consequently the felspar has been reduced to kaolin. There are certain long joints where the clay is whitest and purest.

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Mr. MATTHEW BLAIR exhibited a small collection of Arctic Shells from the clay-beds near Lag, at the south end of Arran, and made some remarks upon their probable connection with ice-movements in that district. The shells are all fragmentary, and the clay is evidently not now lying as originally deposited, the probability being that here are the remains of Post-tertiary beds pushed by ice-action from a lower to a higher level.

The HON. SECRETARY (Mr. Murdoch) exhibited specimens as follows:—

1. Serpentine with Chrysotile, from Colafirth, Shetland, the only known locality for the latter mineral in Scotland until specimens of Serpentine containing it were found by Mr. John Smith in the Boulder-clay near Girvan. [See page 164.]
2. Steatite from the "Klebber Name Rock," a huge mass of the mineral which stands out cliff-like in the north end of Fethaland, Shetland. The softness of the rock, which allows it to be easily cut with a knife, has induced visitors for many years past to carve their names and initials upon its face, and the present specimen is part of the inside circle of a large O in the name *Victoria*, which had scaled off and fallen down.

Dr. R. H. TRAQUAIR, F.R.S., Honorary Member, read a paper, entitled "A Description of the Dentition of a Species of *Janassa*, from Calderside, East Kilbride, Lanarkshire." This fossil fish, in honour of its discoverer, Mr. Wise, he had named *Janassa Wisei*. The type specimen showed a unique example of a fish's head, divided so exactly as to show on one slab the upper jaw and palatal teeth, and on another the lower jaw with its accompanying teeth, an almost perfect division. The paper was illustrated by specimens, casts, and diagrams.

Dr. TRAQUAIR made some remarks upon the specimens of Fossil Fish, *Dipterus Valenciennesii*, from Auchencraig, a quarry ten miles south of Thurso, which had been exhibited by Mr. M'Farlane at a previous meeting of the Society. [See page 160.]

SOCIETY'S ROOMS, 207 BATH STREET, 12TH APRIL, 1894.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

Mr. JOHN SMITH, *V.P.*, exhibited specimens of Carboniferous Amber, containing microscopical plants, occurring in the Ayrshire Coalfield at Stevenston and Kilmarnock. It is known as Middletonite, from its first discovery at the Middleton Collieries, near Leeds. The only other locality where it is occurs in Britain is in the neighbourhood of Newcastle, and it is classed by mineralogists as one of the rarest of the hydrocarbons. Mr. Smith's remarks were illustrated by specimens, by sections shown under the Society's microscope, and by enlarged drawings of the plant remains. [This paper will be given in full in the next part of the *Transactions*.]

The HON. SECRETARY (Mr. Murdoch) showed some fine specimens of Barytes, and part of the root of a Carboniferous Tree (*Stigmaria ficoides*),

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from the higher part of Eaglesham, Renfrewshire, which had been sent for exhibition by Mr. Allan Gilmour younger of Eaglesham. The latter specimen, which must have been transported by ice to the place where it was found, contained a portion of the large central pith, with its characteristic markings. Its perfectly round form showed that the root must have been fossilized while in a growing position, and without being crushed.

Mr. ROBERT DUNLOP read a paper, entitled "Some Notes on a Cycling Tour from Kilmarnock to Castle Kennedy, Wigtownshire." The paper was illustrated by an extensive series of photographic slides, prepared by the author from photographs taken on his trip, and shown by the oxy-hydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH MAY, 1894.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

Mr. L. C. Cooke, Geological Lecturer to the Technical College, 204 George Street; Mr. Richard F. Farrell, 97 Union Street; and Mr. James Goldie, 40 St. Enoch Square, were elected Ordinary Members.

The HON. SECRETARY (Mr. Murdoch) drew attention to a proposed testimonial—in the shape of an oil portrait and an autograph album—shortly to be presented to the Society's Honorary Member, Dr. J. R. S. Hunter, of Daleville, Braidwood, on account of his services to scientific knowledge during the last 40 years, and hoped that a number of subscriptions would be forwarded to the local Secretary.

Mr. JOHN SMITH, *V.P.*, exhibited specimens, as follows:—

1. Prismatic Sandstone, from Saltcoats. When the Caledonian Railway was being made, a bed of very fine grained sandstone, rendered prismatic by its proximity to trap, was passed through. Thinking from its appearance that it would make a good whetstone, Mr. Smith took a specimen, but on attempting to work it into shape he found it to be exceedingly hard, taking a polish and glitter like a cut agate.
2. Pisolitic Ironstone, from Annick Lodge, found in connection with the main coal. The whole band is not pisolitic, but partly much the same as the Lanarkshire "slaty band." The pisolitic part is in great measure made up of innumerable small white sub-globular particles, the largest seldom exceeding half a millemetre in diameter. These show a tendency to gather into lenticular clusters, not often beyond half an inch in their largest diameter. They do not appear, as is usual in pisolitic or oolitic rocks, to be made up of concentric coatings round a centre, but simply have one brownish ring outside a white centre, as seen in section. The central white material seems to be a mixture of lime and silica, sometimes stained more or less by the irony colouring outside. How this pisolitic structure has been caused is not apparent, unless, perhaps, from a frothing up of the irony mud by the

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disengagement of gases while yet in a soft state. The greyish irony paste (brownish in transparent section) has a kind of sub-crystalline sub-globular structure. When calcined the white globules do not alter their colour.

3. A Mass of Ostracoda from Kilwinning. In the shale above the Lady Ha' coal of the district are found irony masses, 3 or 4 inches in diameter, which are almost entirely built up of the shells of Ostracoda, the prevailing species being *Berichia arcuata*. How these organisms came to congregate in such masses is not easily explained, unless they gathered in holes in the lake-bottom, when the mud was being deposited. Like the specimen exhibited, the outside of these masses is often slickensided.
4. Black Mica, from volcanic agglomerate at Giffartland, Dalry. This mineral occurs as flattish rounded bits, sometimes over an inch in length. Embedded in agglomerate which lies between the ironstone series and the upper limestone series, along with small pieces of limestone and fragments of Carboniferous shells, these pieces of mica have probably been brought up from the lower limestone series. Numerous specks of mica are also diffused through the agglomerate. That the larger pieces have not been developed in the matrix after ejection, but were brought up from below, there seemed to be no doubt. Mr. Smith had not seen any other Ayrshire agglomerate with mica in it.
5. *Entalis*, from Law quarry, Dalry. In the lower limestone here there are two species of *Entalis:* one smooth, *E. herculea*, de Kon., and one with longitudinal ribs and furrows, *E.* sp.? This genus is closely related to *Dentalium*, but differs from it in having both the anterior and posterior ends cut away obliquely. The shells are generally thick, especially towards the narrow or posterior end, are slightly curved, and in section are seen to be circular. *E. herculea* has been found in the *Productus* limestone of Khund Ghat, India.
6. Black Sandstone from Dalmellington. In Muck Glen just above the village, the Carboniferous strata are cut off by a fault which brings up what the officers of the Geological Survey doubtfully refer to as the middle division of the Old Red Sandstone. In the Carboniferous area there is a bed of black sandstone about 5 feet thick. It is not absolutely black, but would be even darker were it not for a few specks of (apparently) lime throughout the mass, which appear to have been developed when the sand was consolidated. Through the stone are also many crystals of quartz which have been developed subsequent to its formation, but whether as independent crystals, or growths upon previously existent grains, is not evident.

Mr. JAMES NEILSON exhibited specimens of *Stigmaria stellata* from Burn Anne, near Kilmarnock, also specimens of the same species from a sandstone boulder at Garngad Hill, Glasgow.

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Dr. JOHN YOUNG, F.G.S., read a paper entitled "Notes on the Occurrence of Ctenotomatous Polyzoa in the Carboniferous Limestone of Western Scotland. [See page 142.]

The HON. SECRETARY (Mr. Murdoch) read, on behalf of Mr. James Bennie, of the Geological Survey of Scotland, a paper "On the Occurrence of Peat with Arctic Plants in Boulder-clay at Faskine, near Airdrie, Lanarkshire." [See page 148.] The paper was illustrated by a series of specimens of the plants referred to.

SOCIETY'S ROOMS, 207 BATH STREET, 31ST MAY, 1894.

Mr. JOHN SMITH, *Vice-President*, in the Chair.

The CHAIRMAN (Mr. Smith) exhibited a copy of his new work, "A Monograph on the Stalactites and Stalagmites of Cleaves Cove, Dalry, Ayrshire," and gave a short resume of his theory as to the deposition and growth of these calcareous forms.

Dr. JOHN YOUNG, F.G.S., complimented the author on this outcome of his long-continued work at Cleaves Cove, and agreed generally with the theory he had just given as to their formation.

Mr. JAMES NEILSON exhibited specimens of Zeolitic Minerals from the new Lanarkshire and Dumbartonshire Railway, near Bowling, including Prehnite, Analcite, Thomsonite, Lamontite, &c., making some remarks upon their occurrence. He also exhibited (2) a portion of a Glass-pot, shewing radiated prehnite-like structure from excessive firing, and (3) a specimen of Red Stilbite, said to have been got at New Kilpatrick. Mr. Neilson also exhibited a number of Worked Flints, from the Raised Beach at Larne, Co. Antrim, and read some interesting notes on the section there. Photographs of the locality and of the flints were thrown on the screen by the oxy-hydrogen lantern.

Mr. NEILSON read a paper, entitled "Notes on the Geology of County Antrim," which was illustrated by a fine series of photographic lantern slides, lent for the occasion by Mr. William Gray, M.R.I.A., Belfast. These included—Diagrammatic Geological Sections, Ancient Stone and Flint Implements, Crannogs, Sand Dunes, Boulder-clay, Boulders and Glaciated Surfaces, Tertiary Basalt and its relation to the Chalk, Tertiary Flora, Chalk, Landslips, Dykes, Columnar Basalt, Cliffs at Giant's Causeway, Fairhead, Carrick-a-rede, Ballygally Head, Cliffs in Chalk and Red Sandstone, Marine and Sub-aqueous Denudation, including Caves in Basalt and Chalk, Old Red Sandstone and Cambrian Rocks, and River Action. At its close a special vote of thanks was passed to Mr. Gray for the loan of the splendid series of slides used by Mr. Neilson.

The HON. SECRETARY (Mr. Murdoch) called attention to the forthcoming joint-excursion with the Edinburgh Geological Society to Campsie, which was intended as a welcome to their old friend, and conductor on the occasion, Dr. John Young, F.G.S. He hoped there would be a specially large muster of members.

The CHAIRMAN then declared the Session to be closed.

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REPORT OF THE COUNCIL FOR 1891-1892.

The Council of your Society have again to submit their annual report on the work and events of the past year, and they have the satisfaction of stating that, while it has been marked by no special circumstances, there has been a good and encouraging amount of work to record, showing that the Society is by no means standing still and resting upon its oars, but is holding the honourable place for good and high-class work which it had already gained.

The MEMBERSHIP has not increased to the extent that the Council fully anticipated would be the result of the appeal made to members at the beginning of last session, but still has almost held its own. A new circular on the same lines as that sent out last year has again been issued, and will, it is hoped, have the desired result of considerably adding to the roll.

The FINANCES of the Society are in a fairly good state, and will as usual be reported upon by your Hon. Treasurer, Mr. Wight. [For an Abstract of Accounts see page 177.]

The LIBRARY, of which Mr. White, your Hon. Librarian, will give you an account, has been well taken advantage of. It was not considered advisable to spend much money on new books during the year, though a sum of £8 was voted for the purpose. This year it will be necessary to give a little more latitude to the acquiring powers of the Librarian, as he is most anxious to add the works in current Geological literature.

It will be remembered that an arrangement was proposed and agreed to last May by which the Mitchell Library was to take over all the Foreign Publications received in exchange by the Society, the members of course having access to them both for reading and for borrowing. It is to be regretted that the Library Committee has not yet finally adjusted the terms of the agreement, but the Council hope that the arrangement will soon be in working order.

TRANSACTIONS.—A new part, the 2nd of volume ix., is now in the printer's hand. The concluding papers are being arranged for the press, and it is expected that the part will be in possession of the members before the end of this year.

PAPERS AND SPECIMENS.—A considerable number of papers was brought forward during the session, and many specimens were exhibited. [The titles of the papers and short notices of many of the exhibits will be found in pages 423 to 429 of volume ix., part 2.]

The EXCURSIONS of the season were as follows:—

16th April—Mugdock; excavations for the new reservoir. Mr. Joseph Somerville, conductor.

30th April—Devol's Glen, Port-Glasgow. Mr. John Renwick, conductor.

14th May—Glen Fruin Moraine. Mr. Dugald Bell, F.G.S., conductor.

28th May—Corrieburn. Mr. John Young, F.G.S., conductor.

11th June—West Kilbride and Busbie, near Ardrossan. Mr. John Smith, conductor.

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25th June—Nettlehirst, Dockra, and Broadstone, Beith. Mr. Robert Craig, conductor.

There were also four Friday evening excursions—22nd April, Central Railway excavations; 6th May, Bishopbriggs; 20th May, Cessnock Dock; 3rd June, Giffnock, all conducted by Mr. James White.

Several of the excursions were interfered with by the weather, but others were largely taken advantage of.

Thanks are due to Mr. White and to all the conductors of the Saturday excursions for their efforts to benefit the members in this way. The evening excursions were much appreciated, and the Council hope that, as a means of interesting and instructing young members in geological phenomena, they may be continued and even extended in future sessions.

REPORT OF THE COUNCIL FOR 1892-1893.

The Council again present to the members their annual review of last year's work.

MEMBERSHIP.—In spite of deaths and withdrawals the membership has more than held its own during the past session. The Council, however, still think that with a little effort by members themselves the numbers might be largely increased, and they hope that a distinct step in the desired direction will this year be noticeable.

FINANCES.—Your Hon. Treasurer (Mr. Wight) will tell you in his Report that the affairs of the Society, financially, are in a sound condition, though a larger income would doubtless be desirable from many points of view.

The MEETINGS of the session were nine in number, and were attended by about the usual average of members. The papers and exhibitions of specimens were of general and local interest. To the exhibition of specimens at the meetings, the Council attach considerable importance as affording an outlet for the younger members to take part in the work of the Society. Many are in the habit of acquiring specimens, either by their own collecting, or from friends, and these being brought up at the meetings, with remarks, are often followed by more sustained efforts in the form of papers.

PAPERS.—The titles of papers read at the various meetings will be found on pages 153 to 161, as also the notices of specimens exhibited. It will be observed that most of the business is connected with West of Scotland localities—Ayrshire bulking largely in the list, thanks to the energy and observance of Mr. John Smith, *V.P.* After the reading of papers there was frequently a considerable amount of discussion bringing up points of great value, and it was often noticeable that had time permitted this interchange of views would have been further prolonged.

TRANSACTIONS.—The papers noticed above will furnish the material for a new part, which it is hoped will soon be in the printer's hand. The part issued in May last (vol. ix. part 2) contained the major part of all the papers read during the two previous sessions, and has been very favourably reviewed in various influential newspapers.

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The Council decided last spring that as the 2nd edition of Dr. John Young's paper on the Geology of Campsie, which formed the first part of volume i. of the *Transactions*, had run entirely out of print, it would be desirable to issue a new edition brought up to the present date. Dr. Young agreed to make the needful revision, and as during last summer the work has been passing through the printer's hands, it is now upon the point of issue. Whenever ready it is proposed to put it on sale both to the members and to the public.

The Library.—Mr. White, your Hon. Librarian, will submit his own Report on the work, but it may here be stated that there has been a considerable number of the books in circulation, principally the more recent works. The more money that can be spared to acquire such books, the more will the efficiency of the Library be maintained.

For some time past an arrangement has been in progress by which all Foreign Publications and Reports received in exchange for the Society's *Transactions* will be transferred to the Mitchell Library where they can be read or taken out by the members. This arrangement is now nearly completed, a portion of the books having already been transferred.

The Excursions of the spring and summer were as follows:—

15th April—Hamilton Coal Pit. Mr. J. Hamilton, conductor.
29th April—Glen Fruin. Mr. Dugald Bell, F.G.S., and Mr. J. Renwick, conductors.
13th May—Cartlane, Lanark. Dr. J. R. S. Hunter, conductor.
27th May—Glenhove. Mr. Robert Dunlop, conductor.
10th June—The Whangie. Mr. James White, conductor.
17th June—Little Cumbrae. Mr. James Neilson, conductor.
1st July—Pitcon Glen, Kilbirnie. Mr. John Smith, conductor.
8th July—Balmaha, Lochlomond. Mr. James Anderson, conductor.
5th August—Troon and Barassie. Mr. William Armour, conductor.

It will be observed that these excursions were extended to a later period than in any previous year, and there is reason to believe that the extension was appreciated by many of the members.

The Friday Evening Excursions were—5th May, Caledonian Railway, Maryhill; 19th May, the New Sewage Works, Dalmarnock; 2nd June, Nitshill; 23rd June, Drumchapel—and, as in the last few previous years, have been of advantage to those members who could not attend on Saturdays. To Mr. James White who took charge of these evening excursions, and to the conductors of the Saturday excursions the thanks of the Society are certainly due.

The Corresponding Societies Committee of the British Association.—As reported in former years, the Society is on the list of Corresponding Societies, and has been regularly represented at the meetings of the Association by one of the members sent as delegate for the year. This year, however, no member was present at Nottingham, where the meeting was held, and no report of the work of the Committee has yet been received. Several of the schemes came well within the scope of this Society's work, notably the Recording of Erratic Blocks, and Geological

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Photography. In the former enquiry, for some occult reason, Scotland is not included, though your delegate has urged at meeting after meeting her claim to share in this work. In the latter a small Committee from the Council of the Society was appointed to take charge of the work, but, except the receipt of a few geological photographs by the Secretary, little or nothing has been done. The Council hope that next year more progress will be made in this direction.

Loss of Members.—As in previous years, so in this, the Society has lost heavily by death, some of its oldest and most esteemed members having been taken away. It having been proposed that in future notices of the more prominent deceased members should be read at the meetings, it is not necessary here to do more than mention the names of those lately lost to us, with an expression of sincere regret at their removal from our midst—D. C. Glen, F.G.S., James Armstrong, Sir Michael Connal, Thomas Naismith, Dr. Crosskey, Bailie Blackwood of Kilmarnock, R. R. Horne, and the Rev. Canon Macintosh. Notices of some of these gentlemen have already been read, and, with the others, will be printed in the Society's *Transactions*. [See the next part, vol. x., part ii.]

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CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£30 0 0		
Cash in Treasurer's hands,	1 17 7		
		£31 17 7	
Subscriptions for current year, and Arrears (£1),		72 0 0	
Interest,		7 2 9	
Publications sold,		0 12 9	
		£111 13 1	

EXPENDITURE.

Printing *Transactions*—balance,			£22 10 0
Rent, Insurance, and Attendance,	£12 10 0		
Collector's Commission and Petty Charges,	3 6 8		
Printing Circulars, &c.,	5 13 3		
Disbursements by Secretaries and Librarian,	6 8 5		
Subscription to Palæontographical Society,	1 1 0		
		28 19 4	
New Books and Binding,		7 16 0	
Cash in Bank,	£50 0 0		
Cash in Treasurer's hands,	2 7 9		
		52 7 9	
		£111 13 1	

STOCK ACCOUNT.

To Balance to Credit,		£722 7 9
		£722 7 9

By Cash in Bank and on hand,			£52 7 9
,, Funds Invested,			170 0 0
,, Property—			
Books,	£440 0 0		
Furniture, Bookcases, and Microscope,	60 0 0		
Fossils, not valued,	0 0 0		
		500 0 0	
		£722 7 9	

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1893.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£50 0 0	
,, in Treasurer's hands,	2 7 9	
		£52 7 9
Life Membership Subscriptions,		10 10 0
Subscriptions for current year, and Arrears (£1),		72 10 0
Interest,		7 9 5
Publications sold,		4 0 0
Petty Receipts,		1 0 0
		£147 17 2

EXPENDITURE.

Printing *Transactions*,	£62 19 11		
Plates for do.,	3 15 0		
			£66 14 11
Rent, Insurance, and Attendance,	£12 10 0		
Collector's Comn. and petty charges,	4 15 9		
Printing Circulars, &c.,	5 18 9		
Disbursements by Secretaries and Librarian,	7 4 9		
Subscription to Palæontographical Society,	1 1 0		
			31 10 3
New Books, and Binding,			4 16 7
Cash in Bank,	£40 0 0		
,, in Treasurer's hands,	4 15 5		
			44 15 5
			£147 17 2

STOCK ACCOUNT.

To Balance to Credit,			£714 15 5
			£714 15 5

By Cash in Bank and on hand,			£44 15 5
,, Funds Invested,			170 0 0
,, Property:—			
Books,	£440 0 0		
Furniture, Bookcases, & Microscope,	60 0 0		
Fossils not valued,	0 0 0		
			500 0 0
			£714 15 5

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF GLASGOW.

VOL. X.—PART 2.

1894-95, 1895-96.

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1896.

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The Editor begs to state that the Authors are alone responsible for the facts and opinions contained in their respective papers.

JAMES BARCLAY MURDOCH, F.R.Ph.S.E.

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TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XIX.—The Latest Volcanoes of the British Isles. By Sir Archibald Geikie, F.R.S., Director-General of the Geological Survey of Great Britain, *President.**

My first duty to the members of the Geological Society of Glasgow is to thank them for the honour they conferred some time ago upon me in electing me their President. I have, as they know, a keen interest in the welfare of their Society. It is now more than thirty years since my connection with them began, when one of my earliest papers was published in the first volume of their *Transactions*. Since that time, although I have been less frequently among them, my interest in their progress and prosperity has by no means lessened. This Society has done so much good service to the cause of geology in Scotland that when asked to become its President I felt it to be at once a privilege and a pleasure to consent. I have been unable until now to appear before you, and I am sorry to say that even now I have found it impossible to secure leisure enough for the preparation of any formal address for this occasion. I propose, therefore, to speak to you on a subject which, while it cannot fail to have some interest for you, has for myself the great advantage, that having occupied me pretty closely for the last twenty years, it is a topic on which I may venture to speak without special preparation—the story of the last volcanoes that have been in eruption in the British Isles.

You are aware that these islands of ours are specially fortunate in the wonderfully complete record which has been preserved within their borders of the history of volcanic action from the

* Delivered as a Presidential Address on 19th December, 1895.

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earliest geological periods. Indeed, there is, so far as we know, no area of equal dimensions on the surface of the earth where the story of volcanic action has been chronicled so fully and in such wonderfully voluminous detail. From the dawn of geological history down to a time not more remote than that wherein the soft clays were deposited on which London is built, we have a record of many hundreds of volcanoes which have contributed their piles of lava and ashes to the rocky framework of our country. The British Isles stand on what has been called the critical zone of the European Continent, with reference to the Atlantic Ocean—that line where the balance between land and sea shows its oscillations most, where the rainfall is heaviest and the rate of denudation probably most rapid, where the amount of sedimentary material deposited is greatest, and where volcanic energy, always prone to manifest itself on the oceanic borders of a continent, has had the most fitting theatre for its display.

I propose briefly to sketch the story of our youngest volcanoes, which, as you know, were active in older Tertiary times along the great depression, now chiefly occupied by the sea, between the Outer Hebrides on the west and the line of the mainland of Scotland on the east. The eruptions extended from the south of Antrim right through this hollow and the chain of the Inner Hebrides on by the Faroe Islands into Iceland.

It is now many years since I began to study these volcanic records. During the last two years I have been fortunate in being able to devote myself more strenuously to the investigation, visiting many places that had not been disturbed before by a geologist, and extending my wanderings into the Faroe Islands. These islands, though not part of the British group, tell the story of Tertiary volcanic action in some respects even more fully and clearly than our own cliffs and ravines, for the more northerly climate of these remote isles and their copious rains keep the vast cliff-ranges barer than those of Skye, Mull, or Antrim. The precipices are not only less verdurous but far loftier, so that their volcanic piles are displayed on a scale of stupendous magnificence to which we can show no rival. The geological history revealed by these Faroe sea-walls is so admirably laid bare that it can readily be deciphered by passing voyagers along the coast-line. The same type of scenery arising from the same geological structure runs

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all through Iceland. Mr. Thoroddsen, the able and energetic Icelandic geologist, complains in his writings that geological text-books and memoirs are in the constant habit of quoting Etna and Vesuvius as the normal, and indeed only, types of volcanoes. He shows that this is a great mistake, and that in Iceland another and entirely distinct type of eruptions is witnessed. This Icelandic type is of special interest to us, for it is that to which our youngest volcanoes belonged, and which in older Tertiary time was so widely developed, even to the far north of Iceland. Not only in North-western Europe but over vast tracts of North America this Icelandic type of eruption has flooded wider regions with lava than any volcano of the Vesuvian type is known ever to have done. As a preliminary therefore to the study of the youngest British volcanoes, it is highly desirable to make ourselves acquainted with the modern eruptions of Iceland.

One of the first features which strikes us in looking at the history of modern Icelandic eruptions is that they have not formed mountains like Etna and Vesuvius. Their prominent characteristic is the formation of systems of fissures, some of which run N.-E. and S.-W., others N. and S. These rents in the earth's crust extend in straight lines for many miles and descend from the surface of the ground down to the lava-reservoirs underneath. In some cases the lava, welling upward through the fissures, flows out tranquilly, now to one side and now to the other; but in others, and most frequently, a line of volcanic cones formed of slag, cinders, and blocks of lava is piled up along a fissure, the heaps being often so close together as actually to touch each other. Hundreds of such cones may be seen along a single line of chasm. From their base streams of lava escape and flow out on either side.

All geologists are familiar with the description given by Lyell in his "Principles" of the great eruption in the south of Iceland during the year 1783, when the most extensive floods of lava in historic times were poured forth, burying the surrounding region for a distance of forty miles in one direction and fifty miles in another. The early narratives of this stupendous event were not unnaturally somewhat exaggerated, as Mr. Thoroddsen has found on more careful investigation. At the time when Lyell wrote, this Icelandic region had never been adequately examined. It was not exactly known where the lava escaped from, though it was

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attributed to the volcano Skaptar Jökull. From the explorations of later travellers—particularly of Mr. A. Helland and Mr. Thoroddsen—we now learn that those vast floods of lava came out of a fissure about twenty miles long. On this rent hundreds of cones of slag and scoriæ were thrown up. But these were mere pustules in comparison with the volume of lava, and might be likened to the small cones that sometimes form on the surface of a moving lava-stream. The fundamental fact in this and the other Icelandic eruptions is that there is first formed a series of long parallel fissures, and that the lava rushes out on either side from these. Carrying the idea of this arrangement in your minds, you will find that it supplies you with the key to the history of the latest volcanic eruptions of Britain.

Now let us apply this Icelandic experience to the elucidation of the great basalt-plateaux of Antrim and the West of Scotland. Any one who sails along the shores of the Clyde can hardly fail to notice the ribs of dark stone that rise up, sometimes in singular prominence, along the shores of Arran, Bute, the Cumbraes, and Ayrshire. Those great wall-like masses of rock, or "dykes," as they are called, run through the red sandstone of these coasts with a general direction towards the north-west and south-east. Similar dykes traverse the whole breadth of Scotland, the north of Ireland, and the north of England. Many of them can be followed for twenty, thirty, or forty miles; some even for longer distances. Thus the famous dyke which comes out near Robin Hood's Bay, in Yorkshire, runs for some sixty or seventy miles into Cumberland in a tolerably straight line. Now, the latest of these dykes mark some of the fissures that were opened in the earth's crust during the time of our last volcanic eruptions. The dykes are not all of one age, some of them indeed probably go back to the Carboniferous period. But the youngest, most abundant, and most widespread series is no doubt part of the Tertiary volcanic history.

It gives us some notion of the gigantic forces at work during that time when we find the solid earth to have been ruptured in so many thousands of places. And we may form some conception of the size of the subterranean lava-reservoirs when we contemplate over what an extensive region the lava rose in these fissures and solidified there. Each dyke marks not only a fissure but a line

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along which the subterranean lava rushed upward to fill the chasm. Probably in a great many cases the lava cooled and solidified in the fissure without reaching the surface. But in other cases it no doubt did make its way to the surface, and streamed forth there, sheet above sheet, so as eventually to build up the volcanic plateaux, of which only fragments are now left in Antrim, Mull, Morven, Rum, Eigg, Canna, Skye, and the Faroe Islands. The volcanic parts of the Inner Hebrides may have formed originally a continuous volcanic plain, extending along the whole wide hollow from the south of Antrim to beyond the north of Skye. If we try to realise what this plain must have been like when the volcanic eruptions were at their height, we shall probably again find most assistance from the volcanic fields of Iceland. In that island barren deserts of black lava stretch for hundreds of square miles, like frozen seas of rugged stone, with lines or groups of cinder-cones dotted over them. Cinders and ashes, which sometimes have darkened the air around for weeks, fall over these wastes and cover them with a loose mantle of shifting sand, which is afterwards buried under the next lava-floods. If some length of time should elapse between successive eruptions the surface of lava exposed to the atmosphere will decay, rain will wash the wasted rock into the hollows, streams from the high lands will in times of flood scatter mud and stones over the lavas, and in the end vegetation will spring up on the gradually formed soil. Leaves and drift-wood may then be swept down from the hills, and may be buried in the alluvial deposits. The next overflow of lava will seal up these deposits and effectually preserve their records of old rivers. Now, such vicissitudes in physical geography and topography have occurred again and again in the history of the basalt-plateaux of Antrim and the Inner Hebrides.

The depth to which our Tertiary lavas were piled up cannot be certainly determined, because so much of their upper portion has been worn away. Yet in Skye the remaining part is more than 2000 feet thick, while in Mull it exceeds 3000 feet. What a picture these vast relics afford us of the pile of volcanic material which was ejected from thousands of fissures along the wide hollow between the Hebrides and the Scottish mainland! In course of time this great depression was filled up to a depth of more than 3000 feet. The surface of the volcanic fields was

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no doubt, in part, a black lava-desert like those of Iceland. It ran right up to the base of the Western Highlands, sweeping into the mouths of the glens and round the projecting spurs of the hills. Many years ago, in riding through a wild tract of North America, I was astonished to find that the lava-plains of the Snake River in Idaho looked like a vast sea or lake, with no visible volcano from from which the lava could have come. The molten floods had doubtless issued from fissures underneath, and had flowed so equally as to bury all the inequalities of the land below and to run up the valleys just like a great sheet of water. Where the Snake River had cut a ravine some 700 feet deep in the volcanic plain, it had laid bare a section of the successive sheets of lava by which the country had been so deeply buried.

It was that ride among these western lava-fields that first gave me a clue to the history of our own latest volcanoes. I found that the sections on the Snake River reproduced most of the characteristic features in the great sea-precipices of Mull and Skye.

One of the most prominent of these features helps us to realise that though the level sheets of basalt follow immediately one above another, their successive outflows were sometimes separated by wide intervals of time. The basalts are often marked off from each other along the cliffs of the Western Isles by a red layer, which may be traced persistently for some distance. This brilliantly-coloured band is found on examination to consist sometimes of volcanic ashes, but not infrequently of a kind of burnt soil that was formed by the atmospheric disintegration of a lava-surface before the outflow of the next basalt. Here and there, too, between the sheets of basalt lie seams of shale, often crowded with remains of land-plants and enclosing even seams of coal. The lava-fields formed a land-surface, and any vegetation which sprang up on them would yield leaves, twigs, and branches to be washed into the hollows and covered up there until overflowed and preserved by the next streams of basalt.

To my mind, some of the most interesting evidences of the intervals between successive outpourings of basalt are supplied by the traces of old river-channels which are here and there to be found in the basalt-plateaux. For the last two years I have been engaged among the Western Islands in tracing out the

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history of some of these river-channels. You may remember the story of the Scuir of Eigg. In that island there is still visible part of the course of a river which during the volcanic period flowed westward across the lava-plain. This stream cut out for itself a channel in the lavas and carried down from the Western Highlands the sand, gravel, and pine-trees of the hills. Eventually a black glassy lava or "pitchstone" flowed into the river-bed and filled it up, thus burying its shingle and drift-wood and preserving them to the present day. Traces of an older river, or perhaps, to speak more correctly, of the same river at an earlier period of its history, are found in the islands of Canna and Sanday. Thick beds of coarse conglomerate are there to be seen regularly interstratified between the sheets of lava, and full of stones that came from the Western Highlands, but containing also blocks of thoroughly volcanic rock sometimes 8 or 10 feet in diameter, such as may have been thrown out from some neighbouring volcanic vent. These deposits were probably laid down by a tolerably powerful stream.

From the abundant remains of macerated leaves and branches in the shales that separate some of the basalts, it may be inferred that the lava-fields were covered with vegetation over those tracts where the rock had most decayed into soil and had longest escaped from being buried under new streams of basalt. That the stones in the conglomerate consist partly of gneiss, schist, and granite is proof that the river flowed westwards and carried the detritus of the Highland hills for at least thirty miles across the lava-plain. The way in which the conglomerates are interstratified with basalt, volcanic ashes, and ejected stones shows that the river was flowing at the time when volcanic eruptions were taking place. The stream would have its course shifted from time to time owing to its bed being overflowed with lava. Now and again its current would be directed against the base of a volcanic cone, which it would begin to wash down, sweeping along with it slag, scoriæ, and blocks, and strewing them over the flood-plain. In spates, too, it would no doubt bear from the far hills much mud and abundance of leaves, twigs, branches, and even trunks of trees. When the flood subsided, this drifted vegetation, still floating in the water, would be the last material to sink to the bottom of the pools. It is certainly

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interesting to find in these old river-records of Canna that the uppermost layer in the sedimentary intercalations among the basalts is generally charged with plant-remains, and indeed sometimes passes into actual coal. Immediately above each of the carbonaceous layers lie sheets of basalt, whence we see how the stream must have been driven from one course to another, while the lava-plain was being continually heightened by the outflow of more molten rock. This alternation of fluviatile and volcanic conditions has been repeated at least four times in the formation of the plateau of Canna and Sanday. In other words, we seem to have evidence here of four successive effacements of the bed of the river by the eruptions of lava, and four prolonged intervals when the river resumed its flow across the plain.

In tracing the history of the basalt-plateaux we perceive that, as the ancient volcanic plain was built up by successive outflows of lava, until the depth of ejected material amounted to several thousand feet, the molten rock did not flow out eventually as readily as at first, but, unable to find its way to the surface, was impelled into rents in the terrestrial crust or opened a passage for itself to right or left. This took place more particularly at the bottom of the great volcanic pile. Huge sheets of molten rock were thus injected to form what we know as "Sills." These constitute an interesting and remarkable feature in the topography of the Inner Hebrides. Along the north-east coast of Skye, for example, under the great plateau of basalt, the Jurassic shales and sandstones have been injected with massive sheets of rock, which cap the cliffs and run as bands along the face of the precipices.

Such sills or intrusive sheets having solidified deep below the surface, and having cooled there more slowly than the basalts did which were poured out at the surface, have acquired a somewhat different crystalline character. They are coarser in texture, are generally deficient in the cellular structure so distinctive of superficial lavas, and have assumed a peculiar prismatic structure which, in the course of long exposure, gives a columnar appearance to their escarpments.

The picturesque sills of Trotternish in the north-east of Skye are prolonged beyond the northern end of the island into a group of singular table-shaped islets. Far beyond these headlands they reappear in the strangely fantastic group of the Shiant Isles, where

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perhaps the grandest sill in the British Isles presents a columnar face to the northern sea 500 feet high.

The progress of denudation, by stripping off the mantle of lava-sheets, has here and there revealed some of the vents which, either on lines of fissure or independently, served as channels for the discharge of volcanic materials from the interior to the surface. Some interesting examples of these vents have come in my way recently during my yachting cruises among the Western Isles. One occurs at the east end of Canna; another may be seen on the south side of Portree Bay. But the most remarkable group which I have met with lies at the base of the great western precipices of Stromö, one of the Faroe Islands. There a row of vents, probably placed along a line of fissure, rises out of the sea and passes under the great pile of bedded basalts. As a proof of how easy it is to miss even such clear evidence as this coast presents, I may mention that though in the summer of 1894 I sailed close to these cliffs and scrutinised them with some care, I failed to notice the row of vents. I suppose they must then have been in some way obscured by the bad light of a cloudy day. Last summer, however, with the help of bright sunshine, I detected the vents even at the distance of a mile. Turning the yacht's head towards the cliffs we steamed close to their base, and saw distinctly the outlines of at least five old volcanic vents filled up with volcanic blocks, and completely buried under 800 or 1000 feet of bedded lavas. By pulling in a boat to the foot of the precipice, I was able to explore each of the vents, and the sea being calm, to enter the caves which the waves have hollowed in them. So well had they been dissected by the sea that every detail of their structure could be made out, and I was able to bring away a number of sketches, notes, and photographs.

These little Faroe volcanoes, and the example I have cited from Portree, appear to have been vents that never gathered round them any cones of ashes or slags. They were rather cavities blown out upon the surface of the lava-fields, and possibly giving out streams of lava but not discharging much ashes and stones, though it was by fragmentary material of that nature that they were finally choked up. The row of Stromö vents standing near to each other along a line less than half a mile in length must have looked like some of those on the modern lava-deserts of Iceland.

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An interesting record of the external aspect of these vents is preserved in the arrangement of the mass of coarse agglomerate that has filled them. This detritus is thoroughly volcanic. It consists of compacted volcanic dust and stones, and includes huge blocks of slag and scoriæ, which are specially collected in the centre of each vent. The agglomerate toward the sides is rudely stratified, the layers dipping steeply in towards the centre. This inclination is doubtless that of the inner slope of the crater, and shows how the ejected cinders and stones fell back into the vent, and rolled down the sides towards the middle, where an orifice was for a time kept open by the gradually diminishing explosions. When these ceased the craters formed each a cup-shaped hollow on the plateau, eventually filled up by streams of lava proceeding from other vents in the neighbourhood, and the piling of basalt-sheets went on until the row of buried craters was surmounted by hundreds, or possibly even thousands, of feet of lava.

In long subsequent times the progress of denudation, cutting down this vast pile of volcanic material, has exposed a vertical section of the lavas with the row of old vents lying beneath them. But already a considerable part of the evidence has been destroyed by the advance of the waves. One of the five vents has been almost entirely cut away; only a fragment of it adheres to the face of the basalt-precipice, and before many generations have passed the last trace of that buried volcano will be gone. Let us hope that the same process which is removing these volcanic orifices will bring others into sight.

The Portree volcano adds an additional feature to the story told by the Faroe vents. Its cup-shaped hollow, likewise buried under basalt, is partially filled up with a peculiar decayed, ferruginous deposit. The crater in this instance would appear to have ceased to erupt and then to have been filled with water, so as to become a crater-lake, like one of the *Maare* of the Eifel. Into this pool rain washed down the decomposed surface of the surrounding basalts and thus formed the reddish deposit of the crater-bottom. We learn, too, that vegetation flourished around this Skye volcano, for among the fine tuffs which were ejected, and which gathered into muddy pools on the lava-field, large quantities of decayed leaves were entombed, sometimes in sufficient quantity to form coal, a seam of which used to be worked here by the crofters and fisher-folk for fuel.

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In further prosecuting the history of our Tertiary volcanic plateaux, we find that after many hundreds of feet of basalt-sheets had been poured out, another kind of volcanic activity began to manifest itself. At several distinct centres—the Cuillin Hills, Rum, Mull, and Ardnamurchan—masses of a coarse highly-crystalline rock called Gabbro were injected among the basalts. We cannot tell—unfortunately denudation has proceeded too far—whether or not this gabbro ever formed a connection with the surface of the ground. What we now see undoubtedly must have consolidated at some depth, as its large component crystals abundantly prove. But it is quite conceivable that here and there the gabbro did effect a communication with the surface and streamed forth there in flows of basic lava. Nor can we satisfactorily realise, for the same reason, to what extent the intrusion of these mountain masses of gabbro affected the surface of the basalt-plateau. The intrusions took place in sheets or sills that were forced in between the lava-beds that underlay the lava-fields. Many hundreds of these sheets followed each other, the younger ones cutting the older and baking and altering the bedded basalts. Possibly the sites of these stupendous injections were upraised into dome-shaped elevations or "laccolites," like the Henry Mountains, described by Mr. Gilbert, where the superincumbent stratified formations have been pushed upward under huge intrusions of trachyte.

The normal characteristic of our plateaux—the formation of north-westerly fissures—may have been for a time interrupted by the gabbro protrusions, but it was certainly afterwards renewed. The gabbro masses now consolidated were ruptured in the same way that the country had been before, and up the gaping fissures thus produced a new uprise of molten basalt ascended, sometimes for thousands of feet, and possibly even to the surface of the ground. But here, again, we are baulked of evidence by the enormous waste which the surface of these islands has undergone since older Tertiary time. No satisfactory proof has yet been found that the dykes in the gabbro were accompanied or followed by the outflow of more basalt above ground, yet it is suggestive to find these dykes in great numbers sweeping from the level of the sea up to the very crests of the highest gabbro mountains. The Cuillin Hills, for example, which in so many respects are entitled to a high place among British mountains, owe the notched character of

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their jagged knife-edged crests to the intersection of the gabbro by innumerable fissures filled with basalt. A system of north-west dykes may there be traced from their base to their summits, and it is the more rapid decay of these dykes which has cleft the gabbro with such deep gullies.

The sight of these dykes careering over the crests of the Cuillin Hills always fills me with amazement. No part of the geology of our Western Isles impresses on the mind more forcibly the vast waste which even our youngest volcanic eminences have suffered. It is obvious that the topography must have been utterly unlike that of to-day at the time when these dykes were formed. The moment the basalt in the fissures rose to the level of the bottoms of valleys, it would escape there and rush down to lower ground. By no possibility could it ascend 3000 feet higher, unless the present glens and straths had not then been hollowed out. We are thus furnished with a limit to the antiquity of the present scenery of the Inner Hebrides.

The next act in our volcanic drama brings before us still another phase of hypogene activity. What may have been the length of the interval of time taken up by the extravasation of the gabbro and that of the rocks which have now to be considered, cannot even be guessed. Probably it was considerable, for it is marked by a total change in the character and composition of the lava-reservoir underneath the chain of the Inner Hebrides. Through the bedded basalts and through the black basic gabbros and dykes, domes of pale-coloured rocks were intruded. These rocks, formerly called "syenite," are distinguished by their high percentage of silicic acid, and are now known as Granophyres and Granites. Here, again, no evidence remains as to whether these vast protrusions of acid material ever in any way communicated with the surface. Not a trace of acid lavas which may have flowed out from any of these granophyre centres has ever been detected.

Those who are familiar with the scenery of the Inner Hebrides will remember the striking contrast between the black serrated forms of the Cuillin Hills and the golden hue, regular slopes, and conical shapes of the Red Hills. This contrast of external form is a reflex of the great internal lithological difference between the component material of the two groups of eminences. The Cuillin Hills display the characteristic outlines given by

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the weathering of gabbro. The Red Hills exhibit the not less distinctive forms assumed by the granophyres and granites. It is possible, however, that the marked conical shapes of these hills may be to some extent original. The acid rock was probably always more pasty than the liquid basalts, and may have been heaped up into domes or cones like those which the trachytes of Auvergne and the Velay have assumed.

There has been some controversy as to the relative ages of the granophyre and the gabbro, but the question may now be considered as finally settled. An overwhelming mass of evidence has been adduced to prove that the acid rock is the younger. One island which is seldom visited, but where the relations of the two groups of rock are admirably seen, is St. Kilda. After a previous unsuccessful attempt, I was fortunate enough to land on St. Kilda last June. There being no sheltered anchorage at the island, my stay was cut short by a change of wind. But I succeeded in determining beyond all possibility of doubt the relation of the black gabbro and the light-coloured granophyre. Early in this century Macculloch, famous as a geologist and as a caustic writer on the Highlands and Highlanders, published the first good account of the geology of the island. But though he picked up specimens which showed the gabbro traversed by veins of granophyre, he did not examine the actual junction of the two rocks *in situ*, and refrained from drawing any conclusion as to their relative age. A few years ago Mr. Ross, the active and accomplished Provost of Inverness, reached St. Kilda, and brought away ample material for an excellent account of the island. He, too, left the connection of the two eruptive rocks in some doubt, though he inclined to regard the gabbro as the older of the two. On the occasion of my visit, I found, like my predecessors, plenty of fragments lying about, showing the dark gabbro traversed by the pale granophyre. But no long search was needed to reach the actual point of junction of the two rocks. I found the gabbro and basalt riddled with an intricate network of veins of granophyre —exactly as in Mull, Skye, and Rum—but perhaps on even a grander scale than in any of these islands. With sketches, notes, photographs, and a large collection of specimens, I carried off material enough to put the question in dispute for ever at rest. Having successfully finished this part of the story, I proposed to

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devote myself to further research in an island which is as difficult to reach as it may be to leave. Unfortunately, next morning I was awakened by the sound of the anchor being heaved, and found that the wind had gone round to the south-east after a thunderstorm, that the sky looked threatening, and that the captain judged it prudent to start without delay on the homeward voyage. But there is a good deal still to be done on St. Kilda.

It is as difficult in the case of the granophyres as in that of the gabbros to form any satisfactory opinion as to the effect on the superficial topography of the intrusion of these enormous masses of acid material. Possibly there may have been again a tendency to ridge up the basalt-plateaux into dome-shaped elevations. But there was not the same opportunity of so seriously affecting the level surface of the lava-fields; for the granophyres, instead of seeking new points for their protrusion, have generally contented themselves with breaking out at or near to the areas which had already been invaded by the gabbros. This is well seen in Skye, Mull, Rum, and St. Kilda.

But the uprise of the huge domes and cones of pale granophyre was not the final scene in the long volcanic history. After another interval, again probably of long duration, one further series of fissures was ruptured through all the rocks including the granophyre domes. Up these fissures another ascent of basalt took place, leading to the production of yet another series of dykes. Proofs of this latest system of dykes are abundant in Skye, and admirably exposed on the cliffs of St. Kilda. You will thus see how, from the beginning of the volcanic history, again and again at successive intervals up to the close, the formation of fissures has been always a distinctive feature in the phenomena.

The latest dykes seem to be less abundant than those that preceded them. At least they are not so frequent in the granophyre masses. The striking contrast in colour, and sometimes in durability, between the acid and basic material makes the dykes easily traceable in their course within the granophyres. Nowhere is this contrast more strikingly displayed than in St. Kilda, where the black ribbon-like lines of dyke slant up the pale precipices of granophyre. Here, again, the dykes decay somewhat faster than the enclosing rock, and give rise to notches on the cliffs and headlands. In Skye, the tourist may notice at Broadford, on the southern

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face of Ben-na-Cailleach, which rises as a picturesque cone above the village, a dark hump running up the steep slope of débris and wasting rock. This prominence is a broad dyke which, in this instance being more durable than the granophyre, projects from the surface of that rock. These younger dykes again bring home to us the enormous loss of surface which all that western region has suffered since the volcanic period. It is impossible that the granophyre domes could have been exposed at the surface as we now see them; for in that case the basalt, instead of rising up in the fissures across the hills, would have rushed out into the valleys and flooded them with streams of lava.

There is great difficulty in fixing the relative age of dykes. All that can be definitely affirmed is that a dyke must necessarily be younger than the rocks on either side of the fissure which it has filled. How much younger it may be, it is impossible to tell. The only method by which dykes could be distinguished as to relative age would be by the discovery of characters peculiar to the dykes of each epoch of intrusion. Within the last few months my colleagues in the Geological Survey, while working in Skye, have come upon some such characters, which may possibly furnish a key to the solution of this problem and enable us to group at last, in some broad general scheme, the dykes of the whole of the Western Islands where they are so abundant.

Many years ago, when engaged upon the geology of Skye, I noted that the basalt-dykes are in some cases truncated by the granophyre and in other cases traverse that rock; in other words, that some dykes preceded the eruption of the acid rocks while others succeeded it. The more detailed mapping of the Geological Survey last summer has entirely confirmed my generalisation. But, at the same time, as I have just said, it has accumulated data which appear to indicate that a certain appreciable difference in internal structure and composition can be detected between dykes older and those newer than the granophyres. If on further investigation this distinction can be established and carried into other districts, it may prove of the highest importance as a guide to the interpretation of the history of the dykes—so important a chapter in our Tertiary volcanic history. We may eventually be able to follow the changes in the differentiation of the subterranean masses from which the vast succession of dykes was supplied.

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Over most of our basalt-plateaux the latest dykes form the final phase in the volcanic development of the British Islands. Whether any of these dykes actually reached the surface of the plateau cannot now be determined. It is possible that even after the cessation of the granophyre intrusions the uprise of the next group of basic dykes may have led to the outflow of streams of basalt. But all trace of any such lavas has been entirely destroyed. The youngest lava yet discovered is that which has filled up the river-ravine of the Scuir of Eigg. That striking landmark of the Inner Hebrides affords a most interesting illustration of the river-channels and the superficial lava-streams of the Tertiary lava-fields of our country. The Scuir of Eigg, as I have already mentioned, consists of a black glassy lava, like so much pitch or molten iron, which has found its way into the channel of a river that descended from the heights of the Western Highlands and flowed westwards over the lava-plain. The lava has sealed up this channel, burying the gravel of the river, together with the branches and trunks of pine trees which the floods had swept from the distant hills.

When the eruption of this glassy lava took place the river channel must have been the lowest ground in the pathway of the molten rock. The surface of the plateau sloped upward from the stream into the heights on either side. But, in the geological revolutions of later ages, this order of topography has been reversed. The old hills that flanked the river have entirely disappeared, and the channel of the stream has been preserved on a high ridge which, consisting of durable pitchstone, has been better able than the basalt to withstand the forces of denudation. Perhaps of all the monuments of denudation within the British Isles, the Scuir of Eigg appeals most vividly to the imagination. Its pitchstone-lava is not only far younger than the plateau-basalts on which it lies, but much younger than the basic dykes which traverse these basalts. At the west end of the Scuir, on the face of the great precipice, a number of dykes may be seen cutting the successive sheets of basalt, but stopping short at the gravel of the old river-bed. Hence we obtain a glimpse of the comparative lateness of the pitchstone eruption, for it was not only younger than the dykes, but so much younger that there was time enough for the general level of the plateau to be cut down to some of these dykes. The lava of the

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Scuir is the youngest of the superficial eruptions to which a relative date can be assigned.

And now, in conclusion, let me say a few words regarding the changes which the whole of the Tertiary volcanic region has undergone since the subterranean energy ceased. The volcanoes of which I have been speaking belong to a comparatively recent geological period; to a time actually later than that in which the older Tertiary sands and clays were deposited on the sea-floor. Incredible as it may seem, these soft incoherent strata carry us back to a period earlier than that when the volcanic beacons blazed forth from Antrim through the Inner Hebrides and the Faroes into Iceland. Not only has the whole volcanic episode come and gone, but the materials which the volcanoes poured forth—those huge piles of basalt, more than 3000 feet in thickness and many hundreds of square miles in area—have been so worn down and trenched with sea-lochs and land-valleys that they now remain merely as scattered fragments. It seems by no means unlikely that the lava-fields once stretched as a continuous land-surface from Antrim to beyond the north of Skye, possibly even to the Faroe Isles and Iceland.

The contemplation of such stupendous changes of scenery as this volcanic tract has undergone, opens up for us one of the most fascinating departments of geology. In studying it we are led to trace the origin of our topography, and to see how the familiar features of the land came into evidence. Backwards, step by step, we may follow the slow evolution of the present surface, and mark how one form of scenery gradually merges into another still older, until at last we find ourselves in presence of landscapes wholly different from those of to-day. In this retrospect no break or hiatus occurs, though our evidence for the successive stages of change may be defective. It is like a series of dissolving views, where one feature after another fades before our eyes into something different.

I have had occasion this evening to make frequent reference to the proofs of enormous denudation which meet us in a study of the Tertiary volcanic plateaux. The subject is full of interest, and at the same time not without some difficulty. We see that the work done by denudation has been enormous, but it might be thought hardly possible to subject the amount of this work to

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precise measurement. Yet, in this respect, the basalt-plateaux prove to be of special value. The waste of a structureless rock, such as granite, may have been gigantic, but it has usually left no landmarks behind by which the amount can be even approximately estimated. The basalt-plateaux of the Inner Hebrides, the Faroe Islands, and Iceland, furnish, however, a conspicuous and persistent series of datum-lines by which the minimum amount of waste can be actually measured. The horizontal bars that mark the successive sheets of basalt may be followed by the eye across glens and sea-lochs or fjords, from one side to the other, and throughout the whole length of the volcanic area. We can tell how much material has been worn away beneath these lines, though we have no means of guessing how much may have been removed from above them. We thus obtain a minimum estimate of the denudation of the plateaux.

A demonstration that the amount must be far above that minimum is supplied by the dykes which ascend even to the very summits of the plateaux. I have pointed out to you that the presence of these dykes proves the erosion of wide and deep valleys, but it also shows that an unknown and probably vast amount of material has been worn away from the surface of the plateaux. We must remember, too, that the material of the plateaux descends beneath sea-level, and that the glens which have been excavated out of it are also prolonged under the sea. There cannot, I think, be any doubt that our sea-lochs or fjords were originally worn away as land-valleys, and that their present position is due to subsidence. Hence, in estimating the total waste of the plateaux we have to take into account not only what has been removed from the present land but also what has eroded beneath the level of the sea.

These lessons, so forcibly impressed upon us among our own islands, are deepened by a visit to the Faroe Islands. They are there mingled with a feeling almost of bewilderment at the scale on which they are enforced. As we gaze on the vast precipices which tower out of the Atlantic among the northern islands of the group, we cannot but be astonished at the clearness with which the lessons are demonstrated. It is as if we were privileged to be taught by a series of gigantic diagrams or stupendous models. The climate of these northern isles, less genial than our own, has not festooned

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the cliffs and carpeted the steep declivities with so much vegetation as in Skye and Mull. The rocks have been left barer, and one can trace the continuity of their various bands more uninterruptedly from point to point. Nowhere else in Europe can the geologist study more satisfactorily the way in which structure influences denudation. Above sea-level he can mark the progress of the atmospheric forces in their slow sculpture of the land. Within reach of the waves he can trace their effects in the gradual destruction of cliffs, with their varied assemblage of caves, tunnels, arches, sea-stacks, and skerries. Elsewhere he may be deceived by want of structure in the rocks. But there the level lines of bedding, rising from base to summit of cliffs more than 2000 feet high, furnish him at every turn with horizons from which to estimate the amount of waste. He is not left at the mercy of his imagination, though even the most vivid imagination may fail to enable him to form an adequate mental picture of the facts. The bedding-lines rise continually before him as at once a record of the waste and a guide to the calculation of its amount. To the Faroe cliffs, therefore, I would direct the steps of every geologist who, with an eye for all that is grandest in coast scenery, would seek to realise what has been done by the latest volcanoes of north-western Europe in building up the framework of the Continent, what have been the results of denudation since older Tertiary time, and how topographical features are slowly carved out of the solid rocks. Face to face with these noble precipices he will have some of the most momentous lessons of his science deeply imprinted on his memory and his imagination; he will realise more vividly than before the reality of the effects produced by the fissure-type of volcanoes, he will carry away with him a clearer apprehension of the relation between structure and topography, and he will learn more than ever to appreciate the efficacy of the seemingly insignificant forces that are quietly sculpturing the face of the land.

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No. XX.—Evidences of the Most Recent Glaciers in the Firth of Clyde District. By James Anderson, *V.P.* With a Map [Plate IV.].

[Read 18th October, 1894.]

Before proceeding to describe the outlines and markings of what I believe to be traces of the most recent glaciation in this country, I may remark that Dr. Croll's theory necessitates glaciation of both hemispheres alternately, and glacial conditions in either involve also a rise of sea-level. If we could suppose our planet carried no snow or ice at any part, then probably the sea would stand at its normal level; but if a covering of ice is accumulated at either polar circle of sufficient amount to displace the earth's centre of gravity, such a displacement would have the effect of drawing the water of the ocean towards the ice-clad circle, and thus of raising the sea-level in proportion to the degree of displacement. Some geologists, doubtless, do not admit that there is any connection between the causes propounded by Dr. Croll, and glacial conditions and variations of sea-level as their natural effects; while others who grant a limited range to his theory, but admit that the sea-level may have been 100 or 500 feet higher than at present, refuse to believe that it could have been (or alternatively, that there is no proof that it ever had been), any higher, because they see no shell-beds at a higher level, forgetting or ignoring the probability that the existence of such evidence would be an impossibility.

It must not be forgotten that we have no experience of Till in the process of formation, and there is no reason to suppose that it is being formed at the present time in any part of the northern hemisphere. It seems tolerably certain that a modern glacier with a definite continuous motion in one direction is incapable of producing anything like Till; loose boulders and soft mud are the only products under such conditions. No doubt boulders and mud are the constituents of the Till, but they would never assume its consistency, as we know it, without being subjected to the milling and kneading of a great and comparatively stationary mass of ice. This deposit could only be formed under a body of ice of uncertain motion, or with no continuous motion in one direction; but such an ice-sheet,

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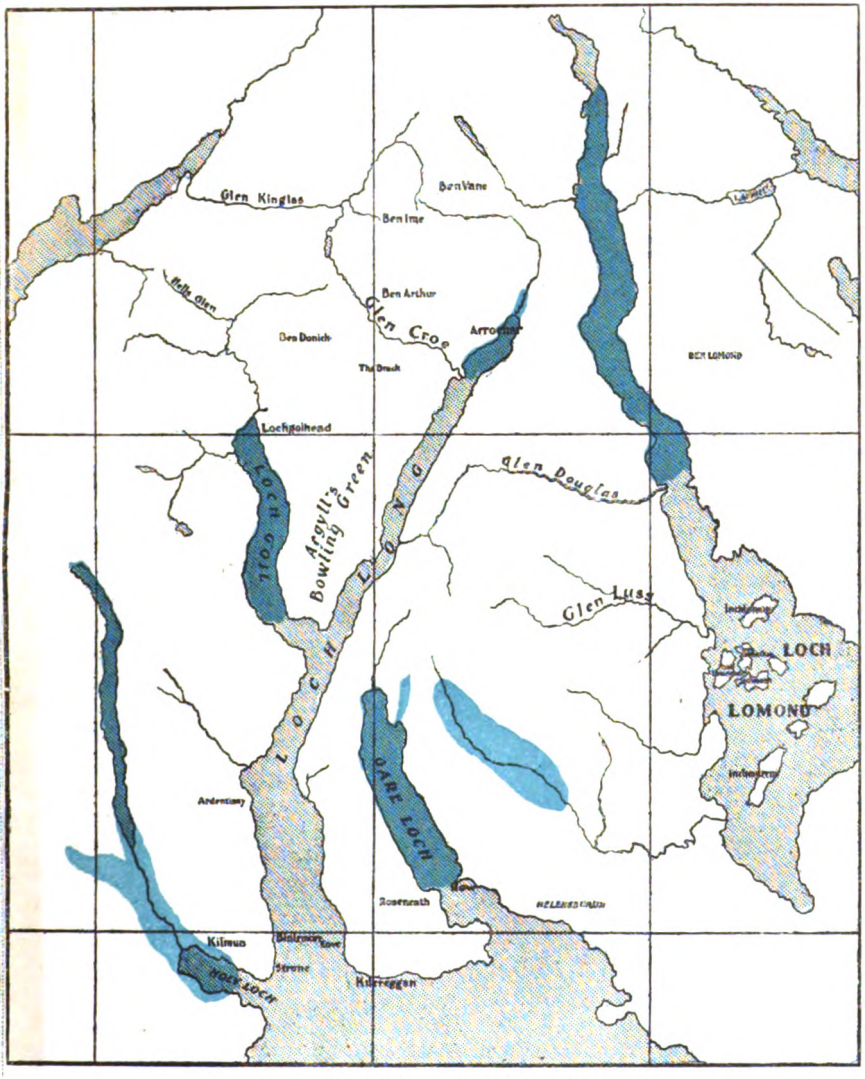

MAP OF THE CLYDE DISTRICT.

Showing the Position of the Latest Glaciers coloured Blue.

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moving ever so slowly, would carry the Till with it to its termination. If I am correct in this, Till-making ice could not exist on land of any considerable elevation, because under such circumstances the whole body of ice would have a steady motion towards the sea-level. Then, the ice that formed the Till must have been stationary at sea-level, and the Till in process of formation would be at the bottom of the ice or about four-fifths of its whole depth below sea-level. If my reasoning is sound, the mere presence of Till would prove that at the time of its formation the sea must have stood at a still higher level.

If we knew the minimum thickness of an ice-sheet capable of forming Till, we might tell the lowest possible limit of the sea-level, and how much below that level the deposit lay at its formation. To insist on evidences of the presence of the sea, or of sea-action under such conditions is futile, for the presence of a body of ice capable of forming Till would remove the sea to its margin, perhaps hundreds of miles away, and the only possible evidence of the presence of the sea that could reasonably be looked for would be the remains of such minute organisms as are capable of existing in the interstices of the ice.

In pointing to a few detached and comparatively slight evidences of glacial action, attributable, as I think, to a very recent and somewhat feeble cold period, I have been actuated by the hope that it might be possible to distinguish between the work of the two most recent cold periods, at least, and to establish contemporaneity between the presence of glaciers and Raised Beaches. For that reason I have confined my attention to those glaciers only which have left traces of a passage towards the Firth of Clyde.

In trying to locate a glacier, I have been guided by the position of deposits which might be its terminal moraine, as marking the point it had reached just before it disappeared, and by the fresh and recent glaciation of the rocks within the limits of its course. For instance, it will be allowed as indisputable that a glacier could not have travelled down the Gareloch further than Rosneath at any time subsequent to the deposition of the gravel banks which are now seen to stretch between the church of Row on the one side and Rosneath church on the other, and which almost close in the loch. Therefore I have taken these banks as the limits of

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the glacier, but it does not necessarily follow that the same glacier did not stretch further down the loch. The probability is that either it or a predecessor of greater power found its way as far down as Camsail Bay.

The whole extent of the old Raised Beach which extends from Camsail Bay to Rosneath Pier is, I think, the terminal moraine formed by the ice flowing out of the Gareloch, and beyond this there is no trace of its presence. A glacier never leaves its moraine like a well-kept lawn. That old beach, now so beautifully smoothed and levelled, was probably dumped there by the glacier in the usual lumpy, hummocky style, and the tide must have been working at that level, sorting out the material as the glacier gradually shrunk back. In all likelihood this Rosneath beach marks the mean level of the tide better than almost any other section. In more exposed positions storms scour away the shore to a point at or even under the lowest ebb-tide, but this old beach occupies a position so sheltered that no waves could strike it with great force.

It is noticeable here that the northern end of this beach, from Rosneath Pier to Clynder, does not show the perfect water-worn contour of the remainder, and the same can be said of the bank on the Row side. The inference would seem to be that the sea had receded from the high level at about the same time as the final melting of the glacier, or at least before the former had time to complete the rounding and levelling process.

Wherever the old shore-line is well seen, and the degree of wave-action can be conveniently compared with the extent of wear and tear effected by the sea at its present level, it will be found that the old level had been acted upon for a very much longer period than the present level has; for the gentle waves of that sheltered inlet to sort and level the broad extent of gravel at Rosneath must have required a very long period of time.

The difference between the characteristic features of the shores of the Gareloch below Rosneath Ferry and those above Clynder is very remarkable. In the upper section there is a total absence of sandy or gravelly deposits—no morainic matter of any kind. Had the glacier continued to push out its winter crop of such material some portions would remain, but there are none anywhere, showing that from the time it pushed up against Row point its

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dissolution had been rapid and continuous, without any intermittent revival of energy.

The lowering of the sea-level seems to have taken place suddenly. There is no evidence of its being gradual or by steps at a time. Had the change of level been in progress for a lengthened period, in either of these ways, this gravel bank would have shown it in shelves and terraces, or in an even, gradual slope.

The Gareloch glacier had been fed from the high ground between Loch Long and Loch Lomond, where there is an unusually broad and wide catchment area, and one well calculated to receive and retain a great depth of snow. As the snow formed into ice, the configuration of the country would cause it to move towards the Gareloch and Glenfruin. The section which entered Glenfruin has left its footprints with unmistakable clearness—its terminal moraine beginning at the bridge over the Fruin at Chapel. The ice-stream in this case had been fed sideways along its whole length from the high levels to the north, with the result that the flow had been a little athwart the valley. The deepest remaining portion of the moraine is seen pressed up against the south hill opposite the bridge.

The whole valley of the Fruin, from Chapel downward to Loch Lomond, is filled with deposits of gravel, which I believe to be glacial morainic matter—probably left by a succession of glaciers, and, no doubt, this accumulation had been of much greater extent before the Fruin scoured out its channel through it. The glacier which finished its career at Chapel, had, I doubt not, pressed on in its prime for a further distance down the valley, but how far and how much of the gravel deposits were left by it is now impossible to say.

The suddenness of the change from glacial to mild conditions is well seen in Glen Fruin. From Chapel to the head of the glen the valley is free from mounds, and, except for the washings of soil from the hills, is as clear as when the glacier was sweeping it of all loose material. Had the departure of the glacier been a gradual process it would have been marked by stages, leaving at each pause more or less of morainic matter, but the complete absence of such deposits forces the inference it had been so suddenly deprived of its supplies that, ceasing to move on, it rapidly melted where it lay. That such was the case seems to be borne out

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to some extent by the existence of various small deposits which seem to have been piled up by the streams against the retreating ice. Notable instances of these are to be seen at the bridge crossing the stream at the very head of the glen, at the farm of Strone. So far as I have observed, none of those recent small glaciers have produced anything of the consistency of true Till.

Crossing over to Loch Lomond we find no trace of recent glacial action anywhere on the islands or shores of the lower, and wider, portion of the loch, but all the exposed rock-surfaces are excessively weathered and decayed. The first unmistakable traces are to be seen about Rowardennan, where round the pier the action of the ice is to be seen so fresh that it might be, so far as appearances go, only a few years old. The contrast between the appearance of the rocks on which the ice has recently operated and that of the earlier glaciated surfaces, suggests the idea that the lapse of time between the older and the more recent glaciation must have been immensely greater than the period which has passed between the disappearance of the last glacier and the present time.

Loch Lomond is almost divided into two sections by a shoal crossing the loch at Rowardennan, on which there is only from 10 to 20 feet of water, and I have set down this bank as the terminal moraine of a glacier which filled the upper half of the loch. There is a very marked difference between the physical features of the two sections; while the lower is nowhere very deep and is broken up with islands, the upper section is a long narrow trough of great and comparatively regular depth which, there is little doubt, had been scooped out when the Till was formed. There are very marked evidence that it was filled with ice at the most recent glacial visitation, but probably several glaciers have successively occupied this trough since it was first hollowed out. It is bounded at several points by rocks standing nearly perpendicular, which, instead of showing glaciated faces, present a distinctly jagged and torn appearance, and this leads me to infer that a glacier requires the force of its own weight to enable it to produce a perfectly glaciated surface on the rocks it passes over.

About Rowardennan the ice does not appear to have risen to a great height. An abundance of very freshly-polished rocks up to 10 or 15 feet above the level of the loch is to be seen, but towards

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Inversnaid the markings rise on the hillside, and are especially well defined on the west side of the loch between Tarbert and Ardlui. The line of the new railway has been cut through finely ice-marked rocks nearly the whole way between those two points.

Of course we cannot be sure of the condition in which the glacier left its bed in the bottom of the loch, but in all probability it was scraped clear of loose material in the usual way. Not until we go as far up as a point called Rudha Ban do we find anything inconsistent with the recent passage of a glacier. At that place there is a section of a bed of gravel which seems to have been of greater extent before the waves of the loch had removed a section of it, and which seems to have been levelled by water-action when the loch stood about 10 feet higher than at present. There is no possible stream to account for its presence, while a glacier passing down the loch could not possibly have left it in its present position.

From Rudha Ban to Ardlui there is a great accumulation of loose morainic material. The railway has cut through it for some distance, and the hotel is placed upon it. Its presence may be accounted for in two ways. Possibly the glacier which filled the loch from Rowardennan to Ardlui may have received the bulk of its supplies from catchment areas between those two places. In that case it would naturally move away from the point where the greatest amount of supplies had reached it, in two streams in opposite directions. If that were so, it would of course form moraines at both terminals, and the accumulations we now see at Ardlui would be its moraine at its northern end. On the other hand, those accumulations may be the terminal moraine of an embryo glacier of a later period coming from the north.

Loch Long does not show any clearly marked terminal moraine, but its depth may have been so great that any material of the kind which may have been lodged in it, had not come near the surface. The west shore from the mouth of Loch Goil to Ardentinny shows very fresh glaciation, which in most places has ground so deep as to obliterate the old rotted crevices.

On examining Loch Long I was exceedingly surprised and disappointed to find very few traces of a recent glacier. From its figure on the map one would expect it to be the leading line in any system of glaciation; but although it must have been the

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parent stream when a severe degree of glaciation prevailed, the configuration of the country had caused the accumulating ice to flow away to Loch Lomond and the Gareloch on the one side, and to Loch Goil on the other. The mountains about Loch Long are for the most part sharp peaks, and do not present broad areas of high elevation, which in other districts favour the accumulation of great quantities of snow. However it may be accounted for, I think it is certain that no glacier flowed down Loch Long at the time I have been speaking of further than to the mouth of Glen Croe. Even at that point, the usual indications are not very clear and distinct. The gravel-banks and shallows may be the terminal moraine of a glacier which had filled the valley from that point upwards, but it is also quite possible they may be the débris washed down by the Croe Water. The northern face of the bank presents the concave contour that the impact of the head of a glacier might be expected to leave.

Loch Goil presents much clearer indications of the presence of a great glacier, which at its fullest flowed down as far as the narrow part below Carrick Castle, and the Raised Beach near by affords ample evidence of the higher sea-level which had sorted and dressed the ice-borne material.

I shall now turn in the last place, at present, to the Holy Loch. Tributary to the valley of the Eck there are some very extensive high-level areas most favourably situated as gathering grounds for great glaciers. The streams of ice which filled Loch Eck and Glen Messan must have been of huge proportions, and the frontage of the glacier must have presented a bold cliff of ice protruding well into the firth. At the time of its destruction it seems to have reached as far down as the Ferry Point east of Ardnadam pier. The resulting moraine begins at the East Lodge in the Hafton policies, and is continuous up to the pier, Hafton House being situated about the centre. It closely resembles the one at Rosneath, but, being more exposed, has suffered to a much greater extent from storms. The similarity is most striking at the upper end of the moraine, where it stands out with a bold, fresh front, differing, I should say, very slightly from the form and contour last given to it by the vanishing glacier. These two beaches are about the same height, the sea apparently not having had time to do this one much injury, the neatly levelled ridges being all there is to show that they have ever been under water.

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Viewed from Ardnadam Pier that end of the Holy Loch moraine presents a very artificial appearance, which is enhanced by a castellated garden wall built along its top, but it is nevertheless a very striking feature in the landscape as seen from any position up the valley. Large as it is, however, all the visible moraine on this shore is a mere trifle compared with the magnitude of the glacier which deposited it, and there is little doubt that the great bulk of the morainic material brought by the ice lies in the bottom of the firth, which had in that case been much deeper at one time than it is now.

Two or three very freshly glaciated rocks occur at the Ferry Point in front of the high bank I have just described, but these are all the rock surfaces exposed on the shore from this point upwards. In this instance, as in the others I have mentioned, the progress of the glacier seems to have been suddenly arrested when nearly at its fullest power, and it has been then removed without any struggle for existence, as if it had been lifted bodily and suddenly out of its bed. In this case, too, the sea must have retired as quickly as the glacier, for that high bank, with its nearly perpendicular front composed of loose, earthy, and gravelly material, could not have retained its shape for any length of time under the action of tides and storms.

In some of the inner glens in this district there are accumulations of detrital matter in similar situations to those I have described at the head of Loch Lomond, and some of the members may remember seeing a considerable deposit of the kind in Glen Messan. I think these may probably be the results of a recent return of a cold period during which the accumulating snow had never quite attained the consistency of a glacier, nor acquired sufficient force to emerge from the inner recesses of the glens in which these deposits are found.

On the hillside, just behind Ardnadam Free Church, there is a most interesting deposit, a large accumulation of clean, water-worn sand and gravel, quite free from earthy matter. This is neither a terminal nor a lateral moraine, but is, in fact, the product of a stream of great eroding power which emerges from the hills at this point. An interesting problem in connection with it is how this mound came to be arrested in its downward course, and fixed on the steep declivity it now occupies, and there is little doubt

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that this position is owing entirely to the glacier which blocked its downward course, causing it to be piled up between its flank and the hillside.

I have already called attention to some points which seem to me to show that the glacial conditions already described must have continued through a long period of time, and nothing has done more to deepen that impression upon my mind than this great heap of sand and gravel on the hill-slope. It cannot now be more than a fraction of what it once was, for the parent stream has apparently cut away one-half of it, and a smaller stream has breached the other half, while the residue is now being quarried for road-making and for building purposes. The fine, and highly worn, material of which it is composed, leads one to think that the stream had been much feebler at the time of the gathering of this deposit than it is now, having probably had a much more limited drainage area. At anyrate the material it now brings down does not get time to be worn so fine as that of the old heap, which has every appearance of having been deposited at great leisure and with perfect regularity.

There is a smaller deposit on the opposite side of the loch, the origin of which I attribute to similar conditions. It may be seen on the hillside above, and a little to the east, of the Parish Church. Its surface, which is more nearly on the level than the rest of the hillside, is principally used as a kitchen garden, though a part of it, cut off by a stream, is included in the churchyard of Kilmun.

It will be observed that I have dwelt persistently on such points as seemed to me to go to prove that the glaciers described had disappeared suddenly, and my reason for doing so is the bearing which such a disappearance has on Dr. Croll's theory. For the same reason I have remarked on some evidence which goes to prove that the drop in the sea-level occurred about the same time and with equal suddenness. Now, it is an essential element in Dr. Croll's theory that all changes in climate must come about in a regular slow and gradual way. I have never lost an opportunity of searching for indications of markings which would indicate any halt or interval in the conditions, but everyone I have met with goes to prove a clear and sudden drop to the present level, or possibly even to a lower one.

When we consider the conditions which probably accompanied

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the beginning of a cold period on the northern hemisphere, and its gradual extension, we should expect its progress to be steady and regular while its ice-sheet was spreading outwards over the open Arctic seas. Storms would often drive it back and undo the extension of years, while the presence of open seas, though adding greatly to the amount of the snowfall, would also help to melt it, and thereby keep down the total accumulation. But a time in its progress would come when those conditions would entirely change. The ice-sheet had spread out until only a very narrow strip of open sea separated it from the northern shores of Asia and America. The final freezing over of those narrow passages would be a critical though inevitable period in the progress of the ice-sheet, though they might still be accomplished in a gradual way.

But I think it is much more probable that some unusually severe winter would unite the ice with the shore so rigidly that no storm could break up the union. The climatic conditions of the Arctic circle would then change completely and at once. The advance of the polar ice-cap, which had hitherto been chequered and intermittent, would be rapid and absolute; the snowfall would melt no longer, but would remain to be incorporated with the ice; the ice-cap would increase as rapidly as the snow fell, and the closing of all open water would more than double the area over which the accumulations would be in progress. The result of all this might possibly be that the advance of the cold period would make as much progress in a few years as it could have accomplished in a very long period if its advance had still been over open seas; and, with the sudden increase of the ice-cap, the rise of the sea-level might be expected to be equally abrupt.

If the cold period by that time had closely approached its maximum, it might be that the rise of the sea-level, brought about by the increased weight of ice on the Arctic circle, would take place almost wholly within the short period of the sudden spread of the ice-sheet I have described. The work of the cutting into the land and the forming of the Raised Beaches would be done by the waves during the long period of cold which would remain at, or nearly at, its maximum. The retreat of the ice-sheet might be expected to proceed by stages similar to those which marked its advance, and when the time came for the break-up of the ice and

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the re-opening of the ice-bound waters, the level of the sea would fall away as suddenly as it had risen.

As Dr. Croll's theory calls for an equal degree of severity all round the hemisphere, some observers hold that the absence of evidences of glaciation in Northern Asia is sufficient to discredit the whole theory, and so far there seems to be no doubt that no formation like Till has been observed in Siberia.

Where sea-action has formed cliffs along the northern coasts of Siberia, especially near the mouths of great rivers, layers of ice, alternating with layers of fine loam, have been seen. Whole carcases of animals now extinct have been found in such deposits, and most of these belong to certain species not known to have survived the last glacial period. But they must have been living during the formation of those beds of ice and loam in which their bodies are preserved in such wonderful condition; and as they are of distinctly Arctic character and similar to those found in interglacial beds in this and others countries, we may safely assume that the conditions of their existence in Siberia had been equally severe.

Siberia as it is at present suffers from deficient rainfall, owing, it is supposed, to the great distance from oceans subject to a high degree of evaporation. If the climatic conditions became so severe as to close the Arctic ocean with permanent ice, Siberia would suffer from a still drier climate, and the greatly increased weight of snow on the polar circle would raise the level of the sea. Those layers of ice containing the animal remains I have spoken of may mark the higher level of the sea during the period of maximum of recent glaciation in this country, and may really be parts of the ice which actually covered the Arctic ocean when it stood at that higher level.

After the sea froze over for the last time precipitation would, of course, be much reduced or would almost cease, and any snow that did fall would be so dry that it would drift about till it became fixed on ice softened by the sun. The frost would extract the moisture from the bare ground, and the fine upper soil would drift like the snow, becoming fixed like it into layers, as they now appear in those cliffs on the shores of the Arctic sea. If such were the conditions the ice age imposed upon Siberia, it would be unreasonable to expect to find Till there.

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It can hardly be expected that a theory so little amenable to observation and direct tests as that propounded by Dr. Croll would commend itself implicitly to all minds; but it cannot be denied that it furnishes a fairly rational explanation of things which, without it, are otherwise inexplicable. For instance, it is well known that at the present time very much larger quantities of ice and snow are resting on the south polar regions than on those of the north pole. There is also the undoubted fact that this country has been subjected at some time or other to severe glaciation, which may, of course, be capable of explanation. But I may be allowed to say that till some other possible theory is put forward, Dr. Croll's is the only one which gives, to my mind, a satisfactory solution of the attendant difficulties.

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No. XXI.—Remarks upon "Joints" or Natural Fractures in Limestones. By Robert Craig.

[Read 11th November, 1894.]

Introduction.—There are few observers, whether geologists or not, who when visiting a limestone quarry have not perceived that the rock is often full of fractures which have cut the strata into large tabular blocks. At first sight these fractures appear to be confused and without any definite arrangement, but, after examination, they will be seen to bear a great amount of regularity. Although two main sets of them are the causes of the limestone being cut into tabular blocks—the "posts" of the quarrymen—there are, at least, five different sets of fractures all varying more or less in age and character.

The First—or Oldest—Set.—This set is characterized by little or no regularity, the limestone having been split in all directions, most probably through contraction. None of the fractures now remain open, but are generally filled with calcite and other minerals, which have re-cemented the rock into a compact and solid mass. These filled fractures are called by the quarrymen "glass-bands," and when the calcite approaches rock-crystal, the name is appropriate enough, as it appears very like plates of glass running through the limestone. When broken up by blasting, the rock generally gives way at the old fractures, although I have seen a new split made in the rock, before the old re-cemented one would yield. Such re-joined fractures are found in all varieties of rock, and doubtless owe their formation originally to contraction.

The Second and Third Sets.—I have placed these two sets together as they are naturally closely allied; as it is doubtful which is the older or which the younger; and on account of the similar way in which both of them break up the limestone into almost uniform blocks of a tabular character. The one set runs nearly from north-east to south-west, in parallel lines which are distant from each other from four to seven feet, but generally from five to six feet. The other set runs from north-west to south-east in the same parallel lines, intersecting the first set nearly at right angles. The north-west to south-east set of fractures, however, run from one foot to two feet further apart

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than those of the latter set, which causes the resulting tabular blocks to be so much longer from north to south than they are from east to west. Still there are occasional exceptions to this rule.

These fractures cut through the different beds or layers of limestone in perpendicular lines; but when they pass through shale or coal the same is not the case, as they are in such instances found to diverge from the perpendicular as much as from ten to twelve degrees. In the Beith quarries this inclination is towards the north, *i.e.* towards the rise of the strata, which may account for it, and it occurs more generally in the north-west set than in that from the north-east. At Overtoun, Beith, the fractures in the latter go straight down through the shale, and the coal underlying the limestone, without the least apparent departure from the perpendicular. I traced this over a large extent of the worked-out field, and found that here, at least, it was the rule, while the set from the north-west quite as regularly inclined—in passing through the shales and the coal—at an angle of twelve degrees towards the north (rise of the strata).

As already mentioned, it is difficult to say which set of these fractures has priority in age. At Overtoun, I am inclined to think, the north-west set is the oldest, yet the evidence is too meagre to theorise upon, and the two sets may be almost contemporaneous. Both the second and third sets of fractures are distinctly subsequent to the first set of fractures—the re-cemented ones, which they cut through in a manner that leaves no room for doubt as to priority. The breaking up of the limestone into tabular blocks, as above described, doubtless gives facilities for the working of it, but also greatly assists in its erosion by the action of rain-water with carbonic acid which, spreading through the fractures, finds a much greater extent of surface to act upon than in the case of the solid rock. Where the limestone has not been protected by Boulder-clay, or by shale impervious to water, the effects of the erosion would be astonishing had we the means of calculating the amount of waste which the rocks have undergone.

Limestone has been burned in the parish of Beith for more than two hundred years, and some of the old quarries which are still open give evidence of the extent of rock removed for that purpose. Still these artificial workings have yielded a mere nothing when

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compared with the quantity which has been carried off by erosion. There was, at the Townhead of Broadstone, a small stream of water which issued from the limestone outcrop, at the base of the Trearne or Hillhead group of beds. It drained an area of about thirty acres, and I calculate that this burn has carried off, from about the time of the glacial period—from an area of ten to fifteen acres—a thickness of at least twenty-five feet of limestone strata. All this large quantity, dissolved by water holding carbonic acid, has been carried away by this little stream into the larger one, in which it found its way to the firth of Clyde. But for this double set of parallel fractures, the denudation of the limestone would probably not have taken place to the extent it has.

This small stream of fine water, highly charged with lime, joined with another stream, which drained the same limestone more to the east and fell into the Pogree burn at Crooked Dam. The mill of the old Barony of Broadstone stood here, and the united streams afforded sufficient power to drive it. The mill has long since been removed, and even the limestone itself has been largely wrought out by the Glengarnock Iron Company. The first stream has been wholly, and the second partly, diverted from their original courses, and sent down the Bombo Burn, away from the little channel they used to run in, and in which the former carried down such quantities of lime.

The Fourth Set.—Not far separated in age from the second and third sets is another, and very irregular, set of fractures which run from north to south as per compass. These cut diagonally each of the tabular "posts" or blocks, made by the second and third sets, into two triangular blocks, but they are of such irregular occurrence that in a row of twenty blocks, or an extent of about a hundred feet, not one diagonal fracture of this set may be met with, while in the next hundred feet they may be found to occur in perhaps every block. It is not, however, to be understood that they appear and disappear only at these distances, as their occurrence is so very irregular. From a section of limestone which was removed at Overtoun, Beith, there was no doubt that they cut through the blocks of the second and third sets, and therefore must be later in age, but except in their irregular occurrence, they do not differ in any other way from these sets.

The Fifth Set.—This set of fractures differs in character and

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in age from all the others. There is no regularity in their appearance, as they are much wider apart, being sometimes a hundred feet, and often two and three times as much. They run in all directions from north to west, and sometimes cross each other, owing to the different angles of inclination at which they run, though not often. They generally follow a straight line for great distances, and cut through all varieties of rock, whether hard or soft, and are mostly quite perpendicular. In the limestones they cut through the upper and lower beds in a similar manner. They are also found cutting into the volcanic ash, which lies below the Carboniferous limestone strata, as far down as can be traced in water-courses.

The quarrymen, who have names of their own for all kinds of appearances, call every description of natural fractures "backs," those of the set under description being distinguished by the name of "sow backs." The sides of these fractures are coated with a sub-crystalline calcite, which gives them a rough and scurfy appearance very like a sow's hide, and hence the popular name. They are found in the trap, as well as in the Carboniferous strata, and run as straight as a draughted line. In the limestone they cut across all the other fractures, and are therefore evidently younger than them.

"*Steps*" *or* "*Breaks.*"—These are another kind of fractures which show on their sides a displacement of the strata either by an upthrow or by a downthrow, hence the name "steps" given to them by quarrymen and miners. There are at least two, if not three, kinds of "steps," all having their origin in earth movements, and good examples of these may be seen in the two large faults which cross Central Scotland from sea to sea, the one on the south, and the other on the north of the Carboniferous group of strata which fill up the great central valley. Another principal "break" is that which starts near Ardrossan, where it crosses the south end of the trap hill on which the Castle stands. Running nearly up the Duisk Water, and on into Renfrewshire, it passes through Cowden Glen, Neilston, almost in the line of the railway, and along by Barrhead into the Lanarkshire coalfield, where, as I have been told, it can be traced for a considerable distance.

Another set of "breaks" connected with displacement of the strata strikes off from these main faults at nearly right angles and

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cross the strata, but become less and less until they run out altogether. Some of these may possibly continue for over a mile in length, but I have never met with one which crosses from the one main fault to the other. There is also a set found in connection with the whinstone dikes which intersect our mineral fields, but in general the displacement which is allied with it is not of great extent.

A few of the dikes themselves are causes of displacement, the strata being thrown up on one side or the other for many fathoms. Thus coal may be found on one side of a dike at a depth of twenty fathoms, while on the other side the same bed may not be met with till a depth of nearly forty fathoms is reached, a displacement of 120 feet. This does not often happen apart from the main faults, and on the sides of many of the dikes no great difference in the levels of the strata can be found.

I have now mentioned the principal sets of natural fractures which I have found in the mineral fields of North Ayrshire and Renfrewshire. In the harder sandstones of these districts the same fractures are also found, and running generally in the same directions. In a very hard sandstone, found in certain places a few fathoms above the lower limestones, the fractures are similar to those in the limestones, except that the rows of fissures are closer, which causes the tabular "posts" or blocks to be of lesser dimensions; this is caused partly, but not wholly, by the fractures being in double lines with only a few inches of sandstone between them. This phenomenon is also seen in the limestones and other rocks, but in the former its occurrence is very rare indeed, while in the hard sandstones it is quite general.

In the fine-grained sandstones, the "liver rock" of the quarrymen and masons, the fractures described above are nearly always absent. The fifth set only is found in them, as in all the other rocks, with a few "drys" as they are called, and also the "breaks" and displacements.

In a fissile porphyrite at Cuffhill, Beith, at Dunglass, Neilston, and at a few other places, the second and third sets of fractures are nearly as persistent as in the limestones. Many of the fractures in this rock are filled up with veins of impure jasper, which, while the porphyrite was being quarried for drains, could be easily procured.

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Conclusion.—Whether all these natural fissures or fractures are of a contractile mechanical origin I am not prepared to say. No doubt contraction is a powerful agent and plays an important part in the fracturing of rocks, but in the second and third sets there is a regularity in the division of the strata into tabular blocks which possibly requires some other explanation. They hold good from the main post—lower stratum—of the sub-beds of the lower limestone, to the higher Linn beds of the upper limestone; and are thus divided from each other by about two hundred fathoms of the middle coal and ironstone measures. The fifth set may be due to mechanical earth movements, and apparently have some kind of connection with the "breaks" or "steps." However, they generally differ in two main points from the latter; there is little or no displacement in this set, and they pass right through the strata, hard and soft, in straight perpendicular lines, while the "breaks" incline both from a straight and from a perpendicular line. I would attribute them both to the same origin—later earth-movements. But these speculations are going beyond the original scope of this paper, which was merely to point out the phenomena of the natural fractures or "breaks" found in Ayrshire strata, and principally in the limestones.

Note.—That electricity in some of its forms has a connection with earth-movements is a problem which is now engaging the attention of scientific men, as the following quotation will be sufficient to show:—"From direct experiments we know earthquakes can produce electrical phenomena of alarming magnitude in our telegraphic lines and cables. May we not then ask what is the connection between earth-currents so observed and micro-seismic storms? Are they connected with disturbances in the earth's magnetism which are being so studiously recorded in all accessible parts of the globe? Do they hold any relation to variations in earth temperature? In short, what are these movements? . . . . . To science the observation of these disturbances opens a new realm of investigation."*

In this quotation the writer asserts nothing, but the direction of his questions shows how his ideas run on the subject. I have no doubt whatever that the fractures I have attempted to describe in the above paper are chiefly due to "earth-movements," which more than probably have a connection, as yet untraced, with earth magnetism or electricity.

* "Earth-movements," by Prof. Milne, Tokio, Japan—*Geological Magazine*, decade second, vol. ix., p. 482.

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No. XXII.—A New View of the Arran Granite Mountains. With a Map [Plate V.] and Twenty-two Illustrations, drawn by the author. By John Smith.

[Read 14th March, 1895.]

"This little world,
This precious stone set in the silver sea."

"Scenes of a truly Alpine character are very rare in Scotland, and perhaps nowhere occur except in the Cuchullin Mountains of Skye and the Granite Peaks of Arran."—Phillips.

Although the officers of the Geological Survey have not yet tackled the Arran granite, we have had quite a number of private observers who, from time to time, have written upon the geology of the island, and who, in many cases, merely incidentally as it were, have taken notice of the great granitic area, but, so far as I am aware, no one has yet given the granite itself the special attention which it certainly deserves.

A walk through all the Arran granite glens, or even a climb over the tops of the granite hills, is not sufficient to unravel the problem of the structure of the rock, as I know from my experience for some time past. It is only by going round each hill at a height where the granite is bare and free from turf and débris, as well as along the stream courses and over the hills in addition, that the true nature of the rock can be made out, and this task is the one which I, for the past two years, set myself to perform, and the results of which I now propose to give.

Dr. Jameson, writing of the Glen Rosa granite in 1798,* says, "The edges of the strata are distinctly perceived, running for a great extent, emerging here and there from below the loose blocks of granite which have fallen from the top of the mountain, or have been formed from the splitting from the surface of the strata." Although the writer uses here the word *strata* twice in one sentence, he afterwards explains that he thinks the granite is not stratified in the usual meaning of the term.

Headrick in 1807† says of Goatfell, "the whole mountain is stratified."

Ramsay remarks in 1841,‡ "The sides also of part of the south

* "Mineralogical Tour in the Scottish Isles." By Rev. Dr. Jameson, 1798.

† "View of the Mineralogy . . . of the Island of Arran." By the Rev. James Headrick, 1807, p. 43.

‡ "The Geology of the Island of Arran, from Original Survey." By Andrew Crombie Ramsay, 1841, p. 7.

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shoulder of Goatfell, along with many other districts, frequently exhibit a somewhat similar phenomenon, the granite being split into masses of varying sizes, superimposed on each other, and dipping in the direction and at the angle of the descent of the hill, like layers of lava which have flowed over each other, the one being cooled before the eruption of the superincumbent bed. But in the case of the granite, this could not be the case, as it will be afterwards shown that it was formed and consolidated previous to its protrusion through the overlying stratified formations, and consequently no such overflowings could have occurred. It is difficult to assign a reason for this phenomenon, but it seems possible that the melted mass, coming in contact with a cooling substance, viz., the slate, at its surface, refrigerated by degrees downward to the centre, and, as it thus consolidated and contracted, the different layers may have split off from the more heated mass below, in the form which they now assume."

Bryce* often mentions the immense sheets and rhombic masses of granite. Speaking of Cir Mohr granite, he says, "It is disposed in irregular tabular masses, split up into rhombic or cuboidal forms by fissures, independent of disintegration, and coëval with the solidification of the rock. The thinner masses we have called sheets; in both, the divisional planes separating mass from mass, and the fissures perpendicular to them, are alike the result of crystallization on the large scale, and bear no analogy to stratification, which is the result of sedimentary deposit."

Again, he says, "The schistose form has often been described as a true stratification; but this structure is not continuous in one direction as strata are, nor does it exhibit the fracture or incurvation of beds; it is, in truth, but a local modification of the rhombic or cuboid form, under which granite more frequently appears."

Landsborough, the younger, writes,† "Should it be resolved to proceed to Cir Mhor, beware of venturing to pass along the Ceims; for a precipice is in the way, rendering this impossible, and these great slabs of granite on its surface are most dangerous, all the more so that they are not very steep, and one is apt to venture

* "The Geology of Arran, and the other Clyde Islands." By James Bryce, M.A., LL.D., &c. 3rd ed., 1865, p. 59.

† "Arran, and How to See it." By the Rev. David Landsborough. 3rd ed., 1886, page 40.

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upon them. They are slippery, and if once a footing is lost it may be impossible to regain it."

I need add no more quotations, my object in giving these being to show that the stratified-looking, tabular, sheet, schistose, or slab-like arrangement of the Arran granite was well known to those who have written about the island. It is, however, strange, that as these "slabs" lie at all angles from a horizontal to a perfectly vertical position, no one has followed out their arrangement to its legitimate issue, as they would have done had the granite been an evidently sedimentary rock. I believe the reason for this is the apparent similarity, although I hope to show that there really is considerable dissimilarity, in the appearances of these granite slab-like forms.

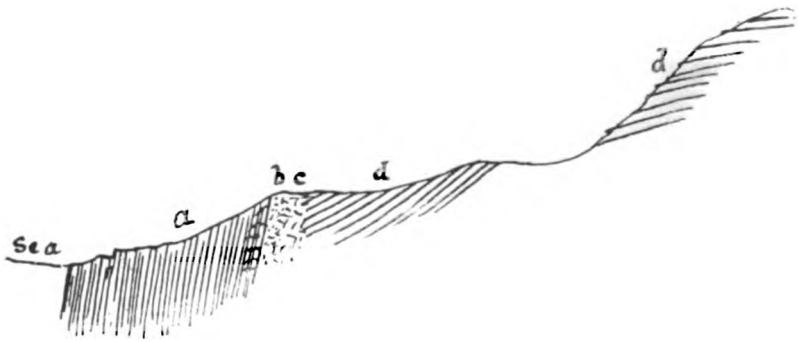

Fig. 1.
Section—Kilbrannan Sound to Beinn Bharrain.
(*a*) Slate. (*b*) Fine-grained Granite.
(*c*) Much-jointed Granite.
(*d*) Granite Slabs.

In the present paper I propose to follow out all the directions and angles of dip of the slabs, noting all their varieties in every hill and glen within the granitic area, and having done so, to draw the conclusions, which, I think, we are led to by a study of the conditions.

It was one day in the summer of 1891, in going up along the Allt Gobhlach (the Y river), that I resolved to trace out the bedded arrangement of the granite. In the course of this stream, which flows directly westwards to Kilbrannan Sound, the slabs are extremely well seen, and resemble, when viewed from a short distance, the courses in a well-bedded sandstone quarry. They dip with the stream, but at a much steeper angle (fig. 1).

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The slate near the line of junction is all but perpendicular, and the granite close up to it is very fine-grained, but coarser at 1½ foot, the particles being very irregular in size. For some distance back from the slate, the granite has completely lost its slab-like nature, and appears in the deep "gullet" of the burn as a much-jointed rock, the joints running in all directions. This structure of the granite, as it approaches the slate, will be repeatedly noted in other localities of the area, and its significance interpreted in the summary. From the junction above noted to the base of Beinn Bharrain (the mount of the hilly district) the moor is comparatively flat, and having regard to the manner in which the slabs outcrop in the Allt Gobhlach, one cannot help remarking the immense amount of marine denudation which has taken place along the western face of the granitic area at a time when the sea worked between the 600 feet and the 1300 feet contour lines.

Near the western base of Beinn Bharrain the coarse-grained granite slabs dip at from 20° to 30°, and outcrop *downwards* on the side of the hill. Some of the slabs, here and in the stream, are quite rotten, but for the most part the granite is very solid, the felspar crystals being about ¼ inch, the quartz ones about ⅛ inch, and those of the biotite ¼ inch in size, and few in number.

Along the shore, near the mouth of the Allt Gobhlach, are many granite boulders, both coarse- and fine-grained. The latter the natives find more difficult to bore than the coarse-grained variety, but, on the other hand, they are much more easily "dressed," and on this account are preferred for building purposes. There are few slate boulders, and those of small size, but the rock is here very shivery and does not lend itself to the formation of boulders. In several exposures between the junction and the shore, the slate is seen to be crumpled, though not to any great extent.

In the south-west branch of the Allt Gobhlach the light-coloured Boulder-clay is of considerable thickness and is only cut through in places by the stream.

At the south-east end of Beinn Bharrain the coarse-grained granite slabs are seen dipping at 45°, or steeper than the hillside, and a little way further round the end of the hill the dip is still steeper. Many of the surfaces of these slabs present a rent appearance, the seams or rents having been opened by weathering, but, until this takes place, there are no openings in the joints.

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Neither are the lines of what become these joints or seams filled by any exfiltration deposit, so that they are perfectly close, with granite to granite; and this is a peculiarity of all Arran granites, unless where slickensides have taken place.

On the col (1800 feet) between Beinn Bharrain and Beinn Bhreac (the speckled mountain, 2333 feet) the fine-grained granite is seen outcropping north-east, and on the east side of the col, near the base of the hill, the junction between the fine- and the coarse-grained granites can be examined. A trap dyke divides Beinn Bharrain from Beinn Bhreac, and in the trap pieces of fine-grained granite occur, these fragments being very much harder than similar granite seen *en masse*. This trap dyke is prismatic across its whole width, minutely so where it is in contact with the granite (fig. 2).

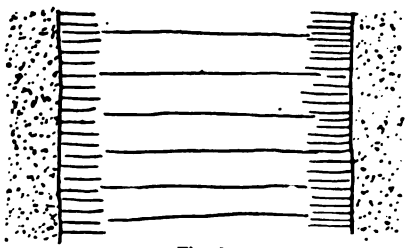

Fig. 2.

Dyke on the Col between Beinn Bharrain and Beinn Bhreac, with small Prisms at sides.

Beinn Bharrain throws out a large spur towards the north-west, and on it the granite slabs are seen dipping steeply N.-E. This mountain has two tops, and on the side of the east one there is a deep corrie or cirque. On the spur, both the ridge and the north end are exceedingly rugged. The watercourses descending from the hill in this quarter are margined with granitic débris, banked up in long ridges to the height of two or three feet. At the north end of Beinn Bharrain there is a very interesting and instructive exposure of the granite. Viewed from a short distance, the slabs are seen to be bent into a very regular curve of large radius, which, before the granite becomes hidden by the turf, dips both N.-E. and N.-W. at about 20° (fig. 3, p. 221). High up on the south-west side of Beinn Bharrain the granite slabs are thick and crop out downwards, and further round towards the south both the slabs and the débris from the mountain are very strongly tinged with hydrated iron oxide.

When we ascend to the top of the hill, the coarse-grained slabs on the west summit, 2345 feet above tide-mark, are found to dip W. at a gentle angle, and on the col between the two

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summits, the coarse-grained slabs are seen to be lying pretty flat, many of them in stacks, having the shape of huge wedges. On East Beinn Bharrain the dip is S.-W., towards the col, at 20°, and on an isolated peak, west from this summit, the dip is also S.-W. at 20°, whilst on an outstanding spur between the two Bheinn Bharrains, the dip is W. On the north-east flank of the mountain the fine-grained granite is seen, and before the col between Beinn Bhreac and it is reached, fine-grained slabs dip at a steep angle to the latter, but they are lying too loose to enable one to say whether they are *in situ* or not.

Fig. 3.
Small Anticline in Granite Slabs, on north end of Beinn Bharrain.

The trap dyke already noted cuts nearly through the col, and was perhaps the cause of the depression from denudation in this part of the range. On going over the top of Beinn Bhreac no outcrops were observed, and the blocks and smaller débris were of fine-grained granite, with occasional ½-inch crystals of felspar. The top, and both sides, are covered with much débris and many blocks, with here and there bunches of heather, the combination having given the mountain its name. On the east slope, especially towards its base, the loose slabs are large, the angles being very little worn, and they are seen in position on the south-east slope, dipping E.-N.-E. at 60°.

Before Corrie-an-Lochan is reached, two hills, 2000 and 1800 feet high respectively, intervene. The first is Muldon (the brown bare-headed hill), and its summit is found to be composed of coarse-grained granite. Below the col between it and Beinn Bhreac, at some distance down the west slope, the coarse-grained granite slabs are found to be lying in an almost horizontal position, and forming small terraces, the edges of which are well rounded. Further down, and still below the col, the slabs dip W. at 20° and 30°.

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On the south side of Muldon the dip is W. at 10°, and at the south-west side the dip is in the same direction, but on the north-west face the outcrops are obscured. Partly surrounding Corrie-an-Lochan (the little loch in the corrie, 1250 feet) is the Meall Biorach (the quey's hill) of the Ordnance Survey, but called by the natives Mulbhira (the sharp, bald-headed hill), a name which does not seem to be at all appropriate. On its west face there is a large conspicuous scree of granitic débris, partly formed of sand derived from the rapid decomposition of the hillside, and at the head of this sandy scree the crumbling coarse-grained slabs dip W. at 60°. At its base there is a sharply-marked terrace cut out of the granite, further down another in the slate, and below the scree there is a deep hollow in the hillside. It is not necessary to suppose that these terraces have been formed since the

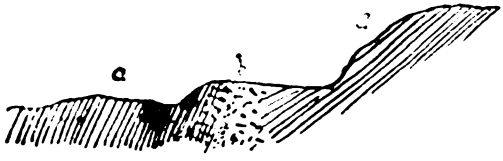

Fig. 4.
Terraces in Slate and Granite, below Meall Biorach.
(*a*) Slate. (*b*) Junction. (*c*) Granite.

glacial epoch, as they are on too great a scale for that (fig. 4). On the moor opposite this hill there are comparatively few granite blocks, the absence of which may be accounted for by the direction the great ice-sheet took in this locality.

The junction of the granite and the slate is not seen in the little stream with the big name, the Uisge Solus Mhor (the large sparkling water), which flows from Meall Biorach, but the latter where last seen, as the granite is approached, is found to be dipping W. at about 80°.

The Corrie-an-Lochan has a fine sandy beach, which, like the granite itself, contains very little mica. This loch is said by the natives to have no bottom and no fish, but it is probably of no great depth, the water being very pure, so that it is like a gem set in the bosom of the mountain. Out of it flows the Uisge Solus Beg (the little sparkling water), and in its channel the coarse-grained granite slabs are seen dipping towards the slate at 40°. The slate

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here dips in the same direction at 80°. The junction is not seen, but, near where it must occur, the jointing of the granite is confused. The lower slope of Meall Biorach towards the loch is much covered with granitic débris, and a little delta of the same material has been formed at the south-east end of the loch; about a third of the way up the hill there is a second corrie carved out of the granite. The loch is oval, the long direction, east and west, being rock-bound, and the position of the delta shows that it has been scooped out by ice. High up above its eastern shore the coarse-grained granite slabs dip to the col of Meall-na-Bheag (the little bare-headed hill) at 15°. Two-thirds of the way up the corrie, on the south-east side, very rotten coarse-grained granite slabs dip to the loch at 50°, and on the south face may be seen, embedded in the coarse-grained granite, a fine-grained granite bullet, dark from the large quantity of biotite it contains. Above the corrie, to the east, on the moor where the surface of the granite is bare for a considerable area, are fine-grained granite veins, up to 15 inches wide, running through the coarse-grained rock.

Here I picked up a large flint scraper, which no doubt had belonged to a primitive inhabitant of the olden time. A shepherd, to whom I showed it, said he had occasionally seen such things lying about the hills.

Between Meall-na-Bheag and Meall nan Damh (the stoat's hill) there is a small loch called Lochan Rhua (the little red loch), which is dry in summer. Here, the natives say, the lightning often strikes, tearing up the turf. Turning round the south-east flank of Meall-na-Bheag, coarse-grained granite slabs are seen dipping S.-S.-W. at 20°, and, at the north-west end of the hill, W. at 40°. Above the deep glen of Catacol (the glen or gill of the battle) there are two "cat stones" (battle stones). On the shoulder of Meall nan Damh, the coarse-grained granite slabs dip S.-S.-E. towards the head of the glen, and on the opposite, or west, side the bedding is rather obscure, but where best seen the dip is W. at 50°. On a terrace on the north side of this hill lies Lochan á Mhill (the little mill loch, about 800 feet), surrounded by a bit of bleak moorland. The north face of the hill towards the loch is steep, and the coarse-grained granite slabs crop out *down-hill* at 50° and 60°. From this coign of vantage is obtained a fine view of the eight green fields situated in the bucht of Catacol, which is carved

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partly out of the slate and partly out of the granite. Some of the trap dykes in the granite are very small, one cutting up through the face of the hill being only 5 inches wide. Amongst the débris forming the screes on the steep hillside may be picked up very beautiful specimens of the granite rock, with perfectly-formed crystals of both quartz and felspar, and sometimes even of mica, in relief.

On the top of Meall nan Damh (1870 feet) the coarse-grained granite slabs dip gently E., with many loose angular and rounded blocks lying about; and on the north brow the dip is N. at 10°. On its north-east slope is much granite débris. This hill is situated near the north-western corner of the granite area, and, though not high, a fine view may be obtained from it. To the east, and near at hand, is seen the large rugged summit of Meall Mhor (the large bald-headed hill, 1602 feet), and away over and beyond the Mull of Cantire rise the Paps of Jura.

A short distance from the source of the Catacol burn, and on its left side, are the china clay "gullets," called by the natives the Schrebhin Clun Shaune. Dr. Bryce says that the china clay occurs in "thick beds," but this is a disappointing description, the clay being simply the fine-grained granite which has been decomposed *in situ*, the purest bits being thin veins about half an inch thick, and very white, running through it, with strongly slickensided sides. The rock here has been subjected to powerful crushing, and is reduced to a mass of shivers, the whole mountain-side having been completely shattered, and nearly every fragment is strongly slickensided. The effects of this immense crushing have not been confined to the Schrebhin alone, and we shall meet with shivered rock in other places, brought about, in all likelihood, by the same great earth-throe. As slickensides are rarely to be seen in the Arran granite, they become the more conspicuous at this place, and tell us of powerful movements after the granite nucleus had consolidated.

Opposite the china clay deposits, and to the east of Catacol burn, is Beinn Tarsuin (the cross hill, 1819 feet). On its west flank the *mid-grained* granite (a variety between the fine- and the coarse-grained) dips W. to Catacol Glen at 20°. On the same side are many, and on the south side immense numbers of, loose blocks of fine-grained granite, which, should one attempt to pass over

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(they lie packed together), will take a good hour's hard work. At one point near its base, towards the south, are the shortest slabs of granite to be seen in the island. They are in position, although the divisional planes are much hollowed out by weathering, and resemble a mass of large double-pointed wedges, closely

Fig. 5.
Short Granitic Slabs, on Beinn Tarsuin.

packed together (fig. 5). Near it there is a block of fine-grained granite, showing slickensides. On the east slope of Beinn Bhreac (1881 feet—the Beinn Bhreac at Lochranza, of the natives—the previously-mentioned mountain of the same name being the Beinn Bhreac Pèni Rioch, although the Ordnance surveyors have made no distinction) fine-grained slabs dip to Loch-na-Davie (the loch with two outlets, the Iorsa Water and the Easan Biorach Water flowing from it).

Near the summit of Beinn Biorach, which is the little hill in the moor to the south of Meall Mhor, there is a coarse-grained granite block with a four-inch white quartz vein running through it, a unique feature, so far as I have seen, in the Arran granite. Some of the granite here has weathered into curious shapes, resembling toadstools, cabbages, &c., large masses being supported on narrow shanks. These features have been, perhaps, brought about by two causes, the granite itself being predisposed to weathering. The first cause is the action of the coarse granitic sand which, when driven along at a rapid rate during strong gales, and impinging against rock stacks, will, like a sand blast, in time undermine them. The second is the action of the frost working unequally on projecting points of rock. Where such bits of rock get wet the head always dries sooner than the foot, there being a "seep" of water downwards, and if this is caught by the myriads of little crystal ice-wedges, before the stone is finally dry, numerous granitic particles will be forced off, and a sufficient number of repetitions of the process will produce such a curious figure as that shown in fig. 6 (p. 226). There are some fine-grained

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granite blocks lying amongst the coarse-grained ones on this little hill, the slabs themselves seen *in situ* being coarse-grained and massive, and dipping S.; the bedding, as is usually the case when the granite becomes massive, being rather obscure. There is a hardened face (the granite is actually much harder than usual and resists weathering better than the ordinary rock) on this hill, running north-west and south-east, which has every appearance of representing a line of fault or shear-zone.

Fig. 6.
Granite Cabbage-like Rock.

Between Beinn Biorach and Meall Mhor the moor is very free from boulders, and the south slope of the latter hill has much drifted granitic sand, and is, in fact, a crumbling mass of coarse-grained granite, in this respect differing from most of the other Arran granite hills. On its top the coarse-grained granite slabs dip E. at 70°, the bedding being rather obscure. The hill-slope towards Glen Easan Biorach (the glen of the quey's waterfall) is not very steep, and is much covered with heather. On the east brow of the hill, opposite Torr Nead an Eoin (the hill of birds' nests, 1057 feet), the coarse-grained granite slabs dip E. at 70°. On the north-west side the dip is N.-W., and the slabs are partly fine-grained. Here the granite presents a striking feature, and viewed from a distance, the slabs—alternately solid and crumbling—look like an outcrop of sedimentary strata, or courses of sandstone alternating with softer marls.

At the junction of the granite with the slate in the bed of the Abhainn Bheag (the little stream), the Allt an Torr (the hill burn) of the natives, there are the usual appearances, but a mass of *coarse-grained* granite is seen in the slate, the two being soldered together. Before the junction is reached the slabs dip to the slate at 45°, and the slate *leans against* the granite at 75°.

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In the Doire Bhuidhe (the yellow thicket) moor the slate is seen to greater advantage than anywhere else on the island. On the summits of the ridge it is strongly *moutonnée*, and in structure has a gnarled and twisted appearance, with many minute cross veins. A magnificent photograph could be obtained of its weather-beaten western face; and speaking of photographs, the higher parts of Arran with their splendid cliffs, peaks, stacks, and corries, appear still to remain a *terra incognita* to the photographer. I searched in vain amongst the local collections, but failed to find a single view showing the naked granite or any of the greater heights.

Between the Abhainn Bheag and the Catacol junction are two large granite boulders, called by the natives Clachan Aitch (the stones of the raven).

Near the mouth of Catacol Glen (the glen, or gill, of the battle) there are considerable Raised-beach deposits, which dip gently seawards. The junction of the granite with the slate here is a very fine one, and of considerable extent. Good ornamental slabs might be cut from the much-twisted slate, which forms a splendid feature in the geology of the glen. A 7-inch vein of fine-grained granite can be traced for a distance of 15 paces from the junction before it becomes hidden by the turf. A vein of eurite, 2 feet 6 inches thick, seen cutting the slate at nearly right angles to its bedding, and soldered to it, can be traced to the granite, and was probably injected into the slate long before it was turned up on end. It is an exceedingly strong and durable rock—much more so than the granite—and would make very handsome monumental stones. Either this vein branches, or there is another vein of the same material near by. The junction of the rocks at this place is called by the natives the Mull-na-Shlabhin (the bare hill of slippery rocks), but on the Ordnance map it is named Madadh Lounie (the wild dog). The first granite slabs seen in the bed of Catacol burn dip gently with the stream.

Opposite Glen Gebhin (the glen of the ridge) there is a perpendicular face of Boulder-clay, with rounded and angular granite boulders, a few of trap, and some horizontal lines of fine sand. At the mouth of Glen Gebhin fine-grained granite is seen in a very shattered condition, and is probably an extension of the shattered zone of the china clay "gullets". Opposite Corrie-an-Lochan in Catacol Glen, and placed about 60 feet above the level of the

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stream, are some lateral moraines of the Catacol glacier. The granite slabs in the bed of the burn are fine-grained, and occupy a nearly horizontal position; on the slope of the hillside, to the east, similar slabs dip to the burn at 10°, and higher up Beinn Tarsuin slope the dip is in the same direction, but much steeper. Above the mouth, and in the bed, of the Allt-in-Calmen (the pigeon burn) fine-grained granite slabs are found lying *in situ*.

In Glen Gebhin, about 20 yards from its mouth, the coarse-grained granite is also much shattered, and 30 paces further up there is a vein-like band in the granite, 8 feet wide, which has decomposed to a clayey mass. Above this, and still further up the glen, the coarse-grained slabs dip with the stream at 15°. Higher up the stream similar rock is again found much shattered, but nothing like a line of fault is to be seen.

On the east side of Catacol Glen, and high above the stream, the granite is much shattered, and opposite the end of Meall nan Damh the shattered slabs dip to the burn with the hill-slope at 50°. About 500 yards above the slate junction, and high on the same side of the glen, fine-grained granite is found lying on the top of the coarse-grained variety. Here the latter rock is much decomposed, leaving large and hard rounded blocks, such as we shall afterwards meet with in Glen Rosa.

Between Beinn Tarsuin and Beinn Bhreac fine-grained granite slabs dip W. at 10°. Although no dykes are to be seen, there is much trap débris on both the west and north sides of the former hill. In fact, from the quantity of trap fragments scattered about in many places over the granitic area there are, perhaps, a larger number of dykes hid below the drift, turf, and moss, than one supposes. Dr. Bryce was of opinion that, by camping out for two nights, it would be possible to trace the line of junction between the coarse- and the fine-grained granites, but it is certain that any part of the granitic area may be reached without camping out, and that the line of junction will never be correctly traced owing to the covering of débris, turf, and moss. Moreover, the fine-grained granite occurs in bedded courses in the coarse-grained variety.

Lichens (the *crotal* of the Highlanders) are powerful agents in bleaching the granite, and, where a dead plant has been washed away, or blown off by the wind, the spot which it occupied is seen to be very white. Peat moss has a similar bleaching power, and,

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in "gullets" where it is cut through by the streams, the underlying granite rock, the boulders, and the clay, are all seen to be extremely white.

Glen Scaftigill (the ravine of shivers) between Beinn Bharrain and Sail Chalmadale (the hill of the twisted heel) is in great measure filled with peat and granitic débris, and little granite *in situ* is seen in it, except near the slate, where it is coarse-grained, and towards the steep upper part of the glen, where fine-grained granite in a very shattered condition is found dipping N.-W. at 70°, possibly a continuation of the belt of broken rock occurring in Schrebhin Clun Shaune. The slate, not far from the granite, is seen in the burn, dipping S.-W., or away from the granite, at 80°.

At the head of the glen, and along the east foot of Beinn Bharrain the Bearberry is abundant, trailing amongst the heather and over the granite stones to a length of five feet. The Dwarf Juniper (the *Gerkinactchy* of the Highlanders) is frequent on the granitic area, especially towards its western parts. Apparently it never gets up its head, but lies prone on the surface of the moor.

Trap dykes are often prismatic across, but the granite veins in the slate, or the fine-grained ones in the coarse-grained granite, are not so.

The stream, Allt an Shurum (the clear burn), which comes out of Loch Tanna (the shallow loch, 1065 feet), occupies the site of an old (pre-glacial) side glen, from which only a small part of the granitic glacial débris has as yet been cleared out by the action of the stream. At its mouth, before it joins the Iorsa Water (the western stream) a large fan-shaped delta has been formed, owing to the impetuous little river not being able to carry the material which it has brought down across a nearly level piece of ground before it reaches the Iorsa, and over this space its waters find an outlet by many little channels. At places where the rock-head has been reached the Boulder-clay is seen to be 30 feet thick, but in other parts it is 50 feet thick, without the bottom being reached. It is always white and sandy with many boulders.

Looking back on Beinn Nuis (the face mountain, 2597 feet) after ascending this burn a good way, a terrace is seen on the side of the mountain, continuous with the stretch of moor on its south-west side, and at the altitude of from 1000 to 1250 feet. The slabs in the Allt an Shurum dip N.-E. with the stream, but at a steeper angle than its bed, viz., 30°.

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Loch Tanna, which is more than a mile long, is situated on a platform corresponding to the lower part of the one already noted on the side of Beinn Nuis, and as no rocks are seen on its banks it is evidently impounded by a mass of Boulder-clay. To the west of it there is a loose block of fine-grained granite in which some of the slabs are only an inch thick—the thinnest I have observed.

Pitchstone, so far as I have noticed in the granitic area, is confined to the east side of the Iorsa Water. The natives call this substance "schechual" and "clach dhu," the former term being also applied to charred peat, a material used at one time by the blacksmiths of the island, in all likelihood to a great extent, in fashioning claymores, before the use of coal became generally known. This fact may throw some light on a class of remains, frequent at one time in Scotland, known as "Picts' kilns," and as to the use of which much conjecture has been expended. These structures, which are elliptical or pear-shaped, and measure about 16 feet by 7 feet, by 3 feet high, were thought by Sir Walter Scott to be primitive lime-kilns, and by popular tradition, distilleries for brewing the famous "heather ale." But they are more likely to have been kilns for the conversion of wood or peat into charcoal, for we now know, from the number and perfection of the remains which have been dug up at various times, that the arts in this country, long before the Roman invasion, had reached a state of perfection, greater, perhaps, than that of a hundred years ago, when, in many parishes, there was not a wheeled vehicle, though the Romans are said to have found the Caledonians well supplied with war chariots.

On North Sail Chalmadale (1572 feet), the fine-grained granite has a reddish tinge, is much shattered, and along the ridge and part of the hillsides its surface is much *moutonnée*. The slabs dip N.-N.-E. at 70°, whilst near the west foot of the hill the dip is N. at 10°.

On the west slope of South Sail Chalmadale (1465 feet) which is very steep and rugged, the granite is neither what can be called coarse- nor fine-grained, but is of a medium variety. The slabs *dip into the hill* (fig. 7, p. 231), a rare feature in the Arran granite, at angles varying from 60° to 80°, so that Glen Scaftigill does not appear to occupy a syncline in the granite, as is the case with so many of the Arran granite glens. The granitic area west of

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Sail Chalmadale has evidently suffered immense denudation at a time when the hills stood lower than they now do, and no doubt this has destroyed what was at one time the anticlinal form of this area; for, compared with nearly all the other hills, it only presents us with a segment of what it evidently once was. There would be no protection for it toward the south-west from the Atlantic waves, which would break with full force on this side of the mountain, the shattered zone of crushed granite which extends into Glen Scaftigill allowing denudation to go on at a rapid rate. On the south side the coarse-grained granite is seen to dip S. at 40°, but the bedding is confused, and this can be accounted for, as the position here cannot be far from the slate.

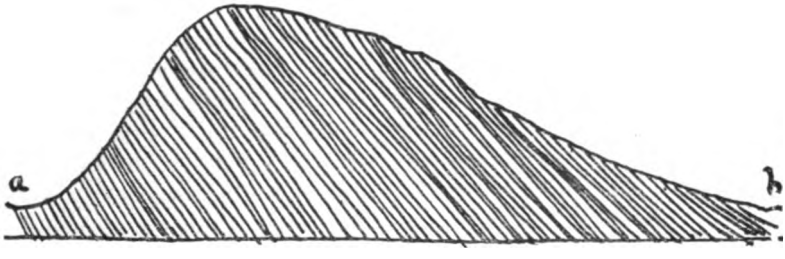

Fig. 7.

Section of South Sail Chalmadale, with Granite Slabs dipping all one way. (*a*) Glen Scaftigill. (*b*) Glen Iorsa.

On the east, or sheltered, side of the hill the slope is very different from what it is on the west, and falls gently down towards the Iorsa, but for all this the dip of the slabs on this side of the mountain is the same as that on the west side, viz., from 60° to 80°, and, in the same direction, some of the slabs being reduced to the thickness of only a few inches.

Going over the top of the hill, the outcrop of the fine-grained granite slabs is well seen, and we detect a loose block which is distinctly, though faintly, slickensided. A little south of the col between the two tops of Sail Chalmadale, the dip is much flatter. From this point of view the slabs on Beinn Nuis are very distinctly seen dipping to Iorsa Glen, and the west side of that mountain is remarkably free from gutters, there being only one at the north end, and a double one at the south end.

Cross Moor, the district between Loch Tanna and the Iorsa, and Beinn Tarsuin and Croc Brack Guy (the windy spotted rock, 1189

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feet), are seen to be very bare of vegetation; and there is a similar bare patch north of Sail Chalmadale, and between it and Dubh Loch (the black loch), about 1200 feet above sea level.

In the Allt an Champ (the camp burn), a little above its junction with the Iorsa, coarse-grained granite slabs dip N.-E. at only 5°, and further up the burn fine-grained ones dip in the same direction at 20°. In the fork, and above the junction of this stream with the Iorsa, are many remarkable hummocky moraines, left by the ice during the close of the glacial epoch.

This side stream got its name from an old practice of the natives to camp out here with their cattle during summer, and remains of their huts are still to be seen in the locality. It presents us at one part with a little glen cut in the solid rock to a depth of perhaps 20 feet, which renders it rather a romantic-looking spot. Growing out of a joint of the granite, and overhanging the glen, there is a much-branched specimen of *Pyrus aira*, the White Beam Tree, rare in this country. It is one of the very few trees in the granitic area, which extends to about forty-one square miles, and has not escaped the notice of the natives, who have a tradition that "once upon a time" a strange bird brought a seed and planted it here, and that out of the seed grew this tree.

The junction of the granite and the slate in Glen Easan Biorach is a very interesting one, as the latter dips down *towards* the granite at 80°, and is very hard; the line of junction being a long slanting one on the side of Torr Nead an Eoin (fig. 8). At the mouth of the glen the slate, which is soft, dips N. at 80°. At Lochranza village the dip is still N., but only at 25°, and the rock is hard, while at the pier the dip is S., the rock still being hard (fig. 9, p. 233). These facts will be of interest when we come to speculate on the origin of the granite slabs and their dip. At, and for some distance from, the above-named junction, the granite is massive and the bedding not

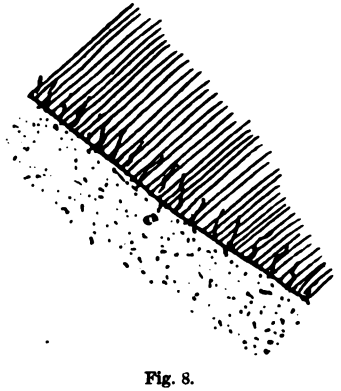

Fig. 8.
Slate dipping down on Granite on Torr Nead an Eoin.

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apparent. It is sometimes fine- but occasionally coarse-grained, *up to the very junction.* As at other junctions, fine-grained granite in the slate occurs in thin veins, and here one of these is faulted no less than five times, the faults being sharp and of small throw, showing that there had been movements in the rock after the

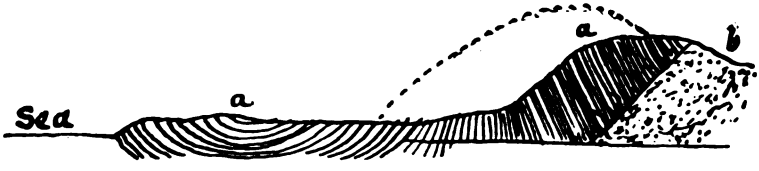

Fig. 9.
Section from Lochranza to Torr Nead an Eoin.
(*a*) Slate. (*b*) Granite.

veins had consolidated (fig. 10). At some parts the granite is soldered to the slate, and in other places there is a parting between the two. Occasionally on the side of Torr Nead an Eoin the granitic surface is so smooth and even, that it looks as if it had not suffered an eighth part of an inch of denudation since the great ice machine was withdrawn from it. During the glacial period the granitic area would suffer most by the loose blocks and débris being carried off wholesale from where the granite was in a soft or shattered condition, the great mass of débris and boulders now lying at the base of the cliffs having in large measure accumulated since that time, although we see myriads of boulders, often of great size, which found a resting-place where they now lie by the breaking down of the powerful agency which was carrying them off.

Fig. 10.
Faults in Slate on Torr Nead an Eoin.
(*a* to *b*) Granite Vein.

At a narrow pass, a little way up the glen from the junction, the granite is in a very crumbling condition, and, in the slope of Torr Nead an Eoin, a deep and narrow ravine has been cut out of similar rock by a very narrow stream, the masses of granite on its sides looking as if they would collapse and tumble down at any moment.

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In fact this "gullet" has the appearance of being the initiatory stage of a corrie, and might, under proper conditions, develop into a cirque, of which, by the way, all the Arran examples are placed well up on the hills.

East of Loch na Davie (1182 feet), at the head of Iorsa Glen and Glen Easan Biorach, are many fine-grained granite blocks, with fine-grained granite in position dipping N. at 70°. Here on the hillside are found many curiously-shaped stones, the like of which

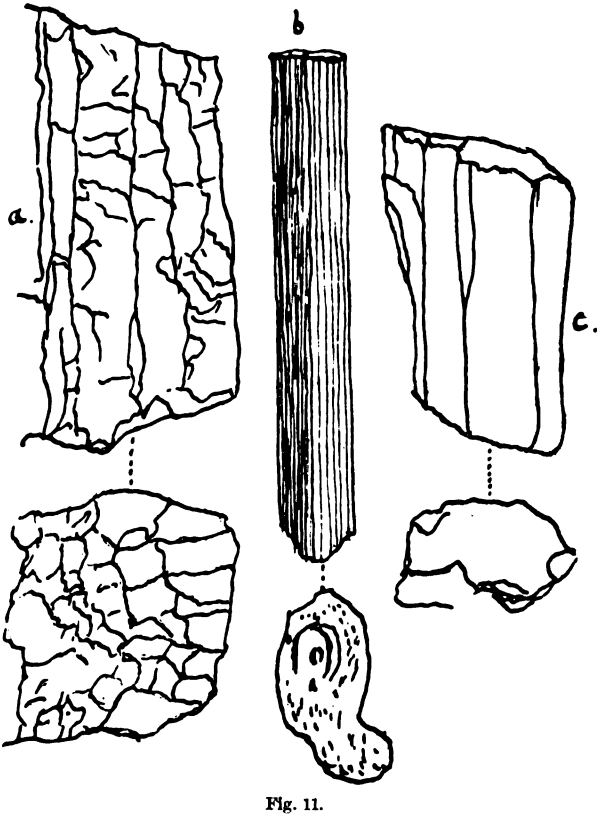

Fig. 11.
(*a*, *b*, *c*) Curiously-shaped Stones.

I have never seen anywhere else (fig. 11, *a*, *b*, *c*). The rock from which they have been derived is not seen *in situ*, but as they occupy a small patch on the hillside below Creag Dubh (the black rock—2000 feet), their parent locality cannot be far away.

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At the north end of the west horn of North Glen Sannox, coarse-grained granite slabs dip W. at 80°, and at the head they dip N. to the glen, with the outcrop downwards. The North Sannox water forks, and in the ridge or spur between the two streams the slabs are seen dipping N. at 15°. On ascending the south-west horn of the ridge which bounds North Glen Sannox, we find fine-grained granite to opposite the middle of Corrie, then the coarse-grained variety for a space, next fine-grained, and then coarse-grained again. From this ridge a magnificent view is obtained of Loch Tanna, Glen Easan Biorach, Iorsa Glen, and North Glen Sannox, with their surrounding mountains.

At the first peak on the ridge the granite slabs are massive and coarse-grained, and dip S.-W. at 70°. At the second peak—a small one—the coarse-grained slabs dip to Allt a Garbh corrie (the corrie of the rough burn) S.-W. at 45°. At the third peak—two peaks together—coarse-grained granite slabs dip in the same direction at the same angle. At the fourth and fifth peaks the coarse-grained granite slabs dip S.-S.-W. at 40°.

When Caisteal Abhail (the fortress of the ptarmigan, 2735 feet) is reached, a magnificent display of coarse-grained granite slabs, forming a high mural face, is seen dipping S. at 35°. Like many other outcrops of the granite slabs, this section would make a splendid photograph. The first word is pronounced *Cashel* in Gaelic (the origin of our word castle), and in an age when people were ignorant of geological causes they might well be pardoned for thinking that rock-structures similar to this were the work of giant and cyclopean hands.

To the south-west of Ceim na Cailliach (the step of the old woman) is a loose pile of slabs, and from this coign of vantage the precipitous face of Cir Mhor (the high crest, 2618 feet) is seen to be seamed with many gutters, which have a tendency to slope towards the right (west).

A wide trap dyke, which cuts through the summit of Ceim na Cailliach, has been denuded away to such an extent that a deep gorge, all but impassable, had been formed, and we see the remains of a sheep which had perished in making an attempt to cross it. The ridge in this gorge is called Druimeich (the horse's back). The natives tell a story of an old woman who was coming from one side of the island to the other, with a load of blankets,

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and, like the sheep, perished in attempting to cross this frowning chasm. There must have been sturdy old women in those days, as a nineteenth century fellow finds his coat quite a heavy enough load to carry up these mountains. From this incident it is said the mountain got its name.

The granite on the summit of this hill is of the coarse-grained variety, the divisional planes of the slabs on the north-east peak (the hound's tooth) having been destroyed by the influence of the dyke; but on the south-west peak (which forms the forehead of the "Sleeping Giant," an imaginary figure well seen from the Great Cumbrae) they are seen dipping S. at 45°. The granitic débris on the north side of the hill is iron-stained.

From the col—near which there is a large boulder—between Ceim na Cailliach and Suidhe Fhearghas (the seat of Fergus, said to have been called after a king of the name who took it into his head to go up and dine on the top), a splendid view is obtained of the face of Cioch na h-Oighe, which is scored downwards with many white gutters, and the slabs are seen plainly dipping to South Glen Sannox.

The side of Suidhe Fhearghas towards this glen is precipitous, but that towards North Glen Sannox slopes more gently, and is covered with much granitic sand and débris. On its north side are found many of the large smoke-coloured crystals of quartz so much prized for cutting into gems. These occur in a few other places, generally in cavities, in the more crumbling coarse-grained granite. On the top of Suidhe Fhearghas the slabs are massive, and dip N. This mountain throws out a large spur to the north-west, and the slabs at the end of it dip N.-W. at 85°, or nearly in a perpendicular direction.

Descending the north side of Suidhe Fhearghas, in the direction of the mouth of Glen Dubh (the dark glen), the slabs are seen to be very "lithy" and schistose-looking. They maintain the high angle which they have on the spur, and being very soft are rapidly decomposing.

Three hundred yards above the junction of North Sannox burn with the Glen Dubh burn, the slabs dip with the stream at 35°. The junction of the rock in Glen Dubh is an extremely interesting one, the slate being perpendicular, and its strike running *end on* to the granite. Much granitic débris and many granite boulders

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are lying on the slate *east* of the glen, and the Boguelly road, going over the Clachan moor, and down through Glen Chalmadale (the twisted glen), to Lochranza, is "metalled" with the decomposed granite. It is one of the most delightful roads one could wish to walk upon, being beautifully soft and white. In the pits by the roadside, from which the material for the road has been taken, there are sub-horizontal iron-stained lines running through the mass.

On the west front of Cir Mhor, the coarse-grained slabs dip W. at 65°. The summit of this mountain occupies a very small area, and there is a precipitous face of, at least, 1500 feet towards Glen Sannox.

On the day I climbed to its top the glens and hills were shrouded in mist, so that the observer felt as if he was elevated above all earthly things except the narrow top of the mountain. Vegetation here is very dwarfed, and *Vaccinium vitis idea*, the Red Whortleberry, is reduced to a very small size, Heather is stunted, and the few other plants seem pinched with cold.

Descending Cir Mhor on its south side, the slabs of the rugged A'Chir (the comb or crest) are seen to dip to Glen Rosa at 60°.

Some of the coarse-grained granite slabs fallen from A'Chir and broken in their descent, are seen to be weathered in from their surfaces as much as 2 or 3 inches, the rock inside the weathered layer being yellowish-coloured, and known as *murchisonite*. On the west and precipitous face of A'Chir, towards its south part, the coarse-grained granite slabs dip W. at 70°, so that we have in this mountain the slabs dipping to Glen Rosa as well as to the Allt a Garbh corrie, and thereby forming an anticline.

The Allt a Garbh corrie is exceedingly well named, as it is filled with a *sea* of immense boulders and loose slabs, extending for at least half a mile, and there is a world of labour in getting over them. The boulders and the spaces between them are often much hid by moss and heather, so that one may sometimes plump in over the head between two large blocks without any warning.

In the hollow between A'Chir and Beinn Tarsuin the coarse-grained granite slabs are seen to dip N. at a gentle angle of 5°, and at the north end of Beinn Tarsuin (of the Beinn Nuis range) the same variety of slabs dip N. at 45°, while further round on its west side the dip is N.-W.

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The junction of the granite with the slate is well seen in some parts of the Garbh Allt (the rough burn), not far above where it meets the Rosa burn, the granite being fine-grained and splintery. For the last quarter-mile of its course the bed of the stream is very steep, falling in that distance about 500 feet, and at the head of this declivity the granite dips at a gentle angle towards the slate. Above this the Garbh Allt flows through a moor in which, at some parts, it has cut a deep channel in the granite, its right bank above the fall being bounded by a high exposure of Boulder-clay, which rests sometimes on the slate and sometimes on the granite.

On the south-east flank of Beinn Nuis the granite slabs dip E. to the Garbh Allt valley. Some of the fine-grained granite veins are very thin, and are occasionally observed to die away in the coarse-grained rock. The east face of Beinn Nuis presents a terrific precipice facing the Garbh Allt valley, and at its foot are to be procured the blackest specimens of pitchstone I have met with in Arran; in some *rounded bits* the layers flake off like the coats of an onion.

On the east slope of Beinn Tarsuin (2706 feet), the display of granite slabs is magnificent. They seem to hang on the mountain side, the dip, as one proceeds northwards, increasing from 45° to 60°; but still the declivity of the mountain is so steep that they outcrop downwards, and in many places overhang. A well-applied charge of dynamite could not fail to detach many thousands of tons from the mountain side.

On the col between Beinn Nuis and Beinn á Chliabhain, already mentioned, the dip is S. at 30°, and, from this point of view, the slabs on the sides of A'Chir can be seen dipping in opposite directions—E. towards the branch of the Rosa, on the one hand, and W. towards the line of the Allt a Garbh corrie, on the other.

Ascending the ridge towards the east, the slabs at the north end of Beinn á Chliabhain (the hill of swords) dip N., and on the west side the dip is W., so that from what we have already seen in Beinn Nuis, the Garbh Allt valley lies in a high-level synclinal trough. The east part of the ridge of Beinn á Chliabhain (2140 feet) is broken up into those large tabular masses, without any apparent dip, which are seen in many places (fig. 12, left side, p. 239). Ascending the ridge from a southern direction, the slabs towards

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its summit are seen, from a certain point of view, to dip *in opposite directions*, W. towards the Garbh Allt, and E. towards the Rosa. At the south base of Beinn á Chliabhain the slabs dip S.-E.

On the west side, and near the top of Beinn Nuis, the dip is towards the Iorsa valley, or *opposite* to that on the east face, indicating that this mountain occupies the position of an anticline. The slabs on the west side outcrop downwards, and are consequently not so steep as the declivity of the hill. Immense quantities of angular and rounded, both coarse- and fine-grained, granite blocks cover its western slope.

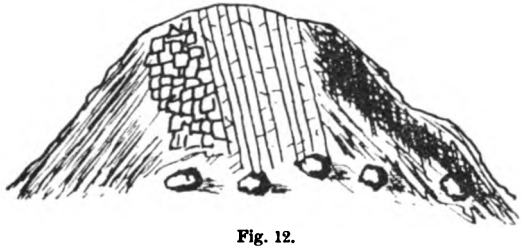

Fig. 12.
Summit of Beinn á Chliabhain, looking south, with Slabs lying up against Tabular Masses.

South Glen Sannox (the sandy glen) is wide, and gently rounded at the bottom, indicating that it had for a long time been filled by a glacier. For a considerable way up both its sides—Suidhe Fhearghas and Cioch na h-Oighe (2168 feet)—there are quantities of coarse grey granite boulders. For a number of years past, the boulders at the bottom of the glen were broken up and shipped to Glasgow to make millstones for grinding china clay, which was not deteriorated by the grinding down of the stones themselves, china clay being the product of the decomposition of the felspar in granite. The breaking up and export of the blocks has now been put a stop to by the Duke of Hamilton, some artists, it is said, having complained that their removal was detrimental to the scenery. The bottom of the glen contains a large amount of débris washed down from above, and no doubt under it many boulders are lying hid.

Towards the head of the glen, and opposite Cir Mhor, the Sannox burn divides, the larger portion coming down from between Cir Mhor and Ceim na Cailliach. In this stream, opposite the north end of Cioch na h-Oighe, the slabs are dipping with

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the burn at 10°. After passing the level part of the glen where lies much sandy débris which has been washed down from the side of Cioch na h-Oighe, a large mound of boulders forms an island in the stream. A short way above, where the glen begins to get steep, the slabs dip N.-N.-E. at 20°. Near the col between Cir Mhor and Caisteal Abhail, at the height of about 2000 feet above sea-level, the granite débris is formed into curious little terraces, which are not easily to be accounted for, but may, perhaps, have been caused by the slipping of the snow on the mountain side.

In the stream which flows down from the south end of Cioch na h-Oighe shortly after Glen Sannox is passed, the coarse-grained granite slabs dip with the stream at about 40°, but sometimes the bed of the burn is steeper, and the slabs outcrop downwards. As we ascend, the declivity of both the hill-side and the slabs increases till the dip reaches 60°.

When I was at this place on 13th August, 1892, a thunderstorm came on, and the vivid lightning seemed to be flashing about one's ears, while the rolling of the thunder among the mountains was grand in the extreme. The downpouring rain was mixed with hail of large size, some particles being very transparent and concavo-convex, yet thick and about $\frac{1}{4}$ inch in length. It descended in drenching, misty sheets, and for a short time everything became obscured, save the tops of Ceim na Cailliach, which looked out faintly through the deluge. I contrived to insert the lower part of my body under a large boulder, but had to be content with my head and shoulders remaining unprotected. At every peal of thunder the underlying rock seemed to tremble.

On the saddle (about 1200 feet) the granite is massive and tabular, the bedding not being apparent. On looking down Glen Sannox, after the storm, I saw below me a rare sight—a most beautiful double rainbow, the whole area within the lower one being lighted up, while the space above the upper one was dark and gloomy. On looking through this Glen Sannox appeared more like a land of enchantment than a reality. Under the peculiar atmospheric conditions Goatfell and Glen Rosa looked very small; but much lower mountains between the saddle and Beinn Nuis had an immense appearance, billows of mists rolling amongst them, and they looked at least twice as high as Goatfell.

This thunderstorm had evidently loosened some of the granite

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blocks, and on going over the ground a week afterwards, I found several, at the base both of Cir Mhor and Suidhe Fhearghas, lying shattered to pieces; occasionally a block embedded in the earth seemed to have been struck, and split into several pieces. One which had come down from Cir Mohr contained more mica than I had ever before seen in Arran.

Going up the west side of Glen Sannox, and keeping well up to where the granite is bare, the slabs are seen to be standing nearly *on edge*. At the end of Suidhe Fhearghas, at the same level, but a little north of the peak, they are very well defined, and are perfectly *vertical*, the strike running N.-W. and S.-E. in the direction of the north end of Cioch na h-Oighe.

About half-way up the glen the granite slabs dip at a little less than the hill-slope, the outcrop being, of course, downwards. Large, *flat*, loose slabs are seen lying on the hill-side between Suidhe Fhearghas and Ceim na Cailliach. Long divisional lines in the granite, which may represent faults, are to be observed at several places on the side of the glen. On the hill-slope, below Ceim na Cailliach, are numerous well-rounded, coarse-grained granite blocks. (Fig. 13, p. 242, is a surface plan showing how one of the slabs *in situ* at a point below this hill is jointed.) Here many fine-grained granite boulders are mixed with the coarse-grained ones, while numerous fine-grained veins run through the coarse-grained granite, there being no distinct lines of demarcation between the two, but still the alteration in grain is sudden.

A story is told of one of the natives, long since dead, who was in the habit of scaling the cliffs somewhere in this neighbourhood for the purpose of procuring as much *gold* as served his turn in this world. He kept his secret well, and on his death-bed would not reveal the locality even to his son, who had not, he said, nerve enough to be able to reach the coveted treasure. After the old man's death, a line of iron spikes driven into a perpendicular face of granite was discovered, but nobody was found hardy enough to scale the height and try to reach the supposed *El Dorado* above!

The head of Glen Sannox, towards the west, forms a corrie, the granite slabs being much cut back by denudation on that side. At first the well-bedded slabs dip towards the side of the glen, then sweep round by Cir Mohr and dip towards the line of the glen,

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and finally they come round its south head by Cioch na h-Oighe and again dip, but in an opposite direction to the first dip, towards the side of the glen.

The head of Glen Sannox, opposite Glen Rosa (the red glen), forms a crag face, which extends for a considerable distance up the hills on both sides. It is the surmounting of this face which is called "going over the saddle," a feat first accomplished by two young ladies, but since that time the route up Glen Sannox and down Glen Rosa has become popular.

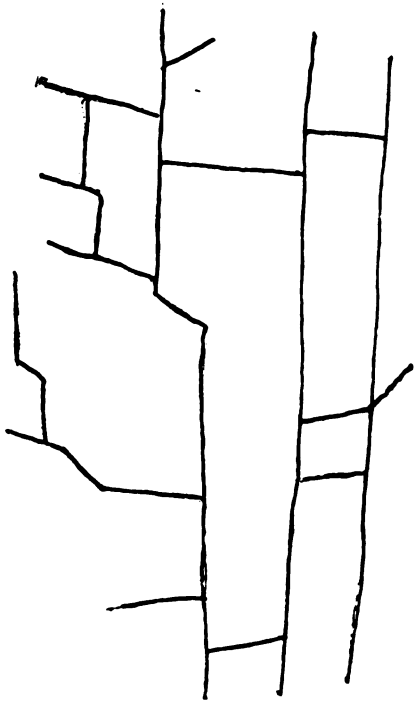

Fig. 13.

Surface Plan showing Divisional Joints of a Slab *in situ*—length, 12 feet.

At the base of Cir Mhor, at the head of Glen Sannox, there is lying about a quantity of pitchstone porphyry, which is of fine quality, that is to say, so far as that it can be dressed by the hammer into shapely specimens. The east slope of Cir Mhor shows the granite slabs dipping towards Glen Rosa, and out-

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cropping *upwards*. There is an immense gathering of them on this slope, and at the south base of the hill great quantities cover the moor for about half a mile. At its south end the granite slabs dip at 20° towards the line of Glen Rosa, so that on three sides of this hill we have them dipping more or less with the hill-slope, the north face being very precipitous.

The junction of the granite with the slate in Cioch na h-Oighe burn (I could get no native name for this stream, which is in the high-level glen to the east of the mountain of the name) is a very interesting one, and has probably been seldom visited by the geologist, as specimens of the granite joined to the slate are most easily procured, which is not the case at junctions which are more readily reached. The burn itself, an insignificant-looking stream, which enters the Sannox burn near the mouth of the glen, at first appears to have no attraction up its course to draw the explorer, with the imposing Glen Sannox before him, but after all, it presents features as commanding as any other stream in Arran, and when one gets fairly into the Cioch na h-Oighe Glen he is quite astonished at its great size.

The granite close on the slate here is fine-grained, but there is a soft parting between the two as if it represented a line of fault, and this idea is strengthened by the fact that the granite is very much shattered. At a short distance from the junction, a small trap dyke, with 8 feet of slate close on it and next to the body of granite, passes across the burn, being parallel to the main body of the slate. The enclosed slate is soldered to the granite, and thin veins of fine-grained granite pass through it. In the bed of the burn, a little above the junction, the slabs of coarse-grained granite dip N.-E. at about 50°, but the bedding is rather confused. The slabs at the north end of Cioch na h-Oighe are seen dipping N.-E.

At one time there has evidently been a great flood in this burn, probably the work of a water-spout, as a large area, including many acres at the head of the glen, has been washed bare of vegetation and débris. The effects have been peculiar, for along either side of the burn banks of boulders and granite débris, 4 feet high, are to be seen, some of the boulders being 4 feet in diameter, and many smashed and broken. Even 20 or 30 yards back from these lines of débris, boulders appear to have been broken by others

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having been driven against them. The two lines extend for half a mile like a pair of lateral moraines, while the whole looks quite fresh and is evidently of recent date.

At the head of the glen the granite slabs dip N.-E. at 36°, and are from 1 foot to 4 feet thick. From this position is obtained a fine view of the whole east side of the mountain, which is steep and in great part bare of vegetation and débris. The granite slabs here are seen dipping with the glen (fig. 14), the dip increasing with

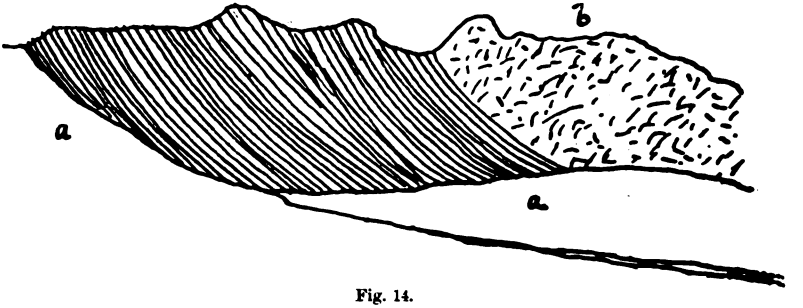

Fig. 14.
View of the east side of Cioch na h-Oighe, showing the Granite Slabs.
(*a*, *a*) Débris. (*b*) Confused Jointing.

the ascent. Towards the north end the jointing is confused. This is perhaps the most magnificent display of slabs, as to extent, in the whole granitic area, as they stretch in unbroken succession for, we should say, a quarter of a mile. In the forenoon of a long summer's day, a splendid photograph could be taken, showing their dip and curvature on the mountain side.

On the ridge which separates Cioch na h-Oighe Glen from Am Binnein Glen, as well as on its flanks, lie immense quantities of boulders and granite slabs. On the south side of the former glen the slabs dip E.-S.-E. at 15°. Near the head of the glen there is a corrie with a sandy patch, and above this the slabs dip at 30°, and higher up still at 45°, in the same direction. At the summit, opposite Am Binnein (the hilly region, 2172 feet), the slabs outcrop on the side of the slope of Glen Sannox, and dip E. at about 10° (fig. 15, p. 245), and from this point a magnificent view of the glen and its surrounding mountains may be obtained. From Cioch na h-Oighe to Goatfell the outcrops of the slabs are very well exposed in many places in stacks and peaks. On this ridge opposite the Rosa saddle the coarse-grained granite slabs dip E. at 15°.

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In the bed of the Rosa burn, about half a mile down from the saddle, the granite slabs dip S., in the line of the glen, and with the bed of the burn. Further down, opposite the north end of Goatfell, hard balls in the crumbling granite or "arkose," 2 to 5 feet in diameter, are to be found. When these are removed from the matrix, they appear as well-rounded *ready-made* boulders. Opposite Goatfell the slabs in the burn dip S.-S.-E. at 20°.

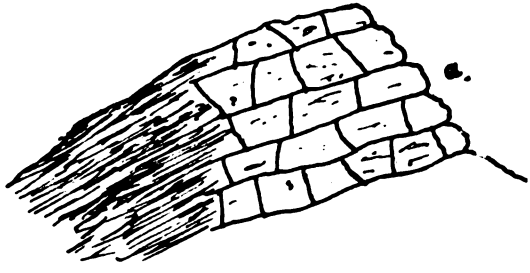

Fig. 15.
Outcrop of Slabs on the east side of Glen Sannox.
(*a*) Upper part of the slope of the glen.

Where the little streams, which come from Cir Mhor and Bealach an Fhir-bhogha (a pass where a man may go), join the Rosa burn, they both cut through a large and thick mass of boulders, the granite rock not being reached in their beds at this point.

Opposite the middle of Beinn á Chliabhain and high on its east side, the granite slabs are seen dipping with the hill-slope to Glen Rosa. At the north end of this hill the granite slabs in the bed of the Rosa burn dip *up stream* at only 5°. Below this the water runs in a deep channel cut in the line of a trap dyke, the individuality of the slabs having been destroyed by heat. This dyke looks like a continuation of the one which cuts through the summit of Ceim na Caillìach. The granite slabs in Glen Rosa at this part form a syncline (fig. 19, p. 246).

About 200 yards above the junction of the Gardh Allt with the Rosa burn, and in the bed of the latter, the granite slabs dip S.-S.-E. and S. at 10° and 20°. At the Gardh Allt junction they are massive, hard, and crumbling, dipping S. at 35°. Here there is another great mound of boulders. The junction of the granite and the slate in the bed of the Rosa burn is not seen, but the latter leans sideways against the granite at about 80°.

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On the west slope of Goatfell (a corrupt name, the original meaning the spike hill), as high up as where the mountain is bare of vegetation, and at the verge where the granitic débris has packed up to, is the best position from which to study the nature of the granite. From the immense smooth faces, extending sometimes to hundreds of square feet without a joint or a flaw, one occasionally is inclined to think that the whole is one solid mass of rock, but wherever a stream has cut 10 or 20 feet into it, the slabs are seen dipping, as a rule, with the slope of the hill, at angles varying from 50° to 60°. On looking up to the untraversable precipices above, the dip is seen to be at even greater angles, increasing in intensity with the height of the mountain.

Where large slabs outcrop *upwards* for a space, one is sometimes tempted to walk along the narrow ledge of footing thus exposed, on the basset edge, which is generally partly covered with a little alpine vegetation, but this is risky, as a single false step would send one down an almost polished surface dipping at 60°.

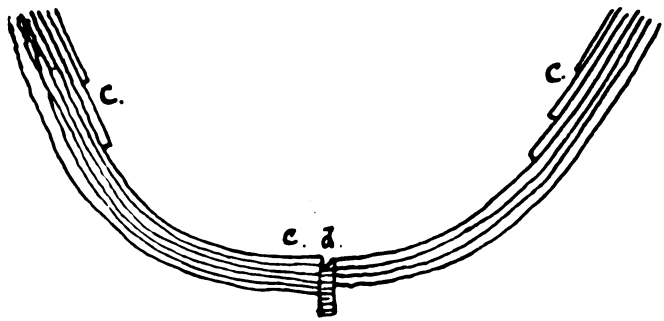

Fig. 19.
Glen Rosa Syncline.
(*c*, *c*, *c*) Granite Slabs; (*d*) Trap Dyke.

On the north-west slope of Goatfell there is a considerable amount of pitchstone porphyry, and in nearly every little stream there are, more or less, fragments of trap, some with bits of granite firmly soldered to them. Although some of the great slabs are fairly free from divisional joints, long cracks, the ends of which often terminate in the *solid granite*, are sometimes seen running along their surfaces. At one part, for about 12 feet of the diameter, the surface of a slab was seen to be traversed by

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numerous cracks similar to those in dried mud. Such rents are generally open—by weathering—for a depth of one or two inches, but no secondary deposits are to be found between the divisional planes, which shows that they have never been open even in the smallest degree.

A sharp shower having fallen shortly before I passed along the slope of this mountain the little streams were "in spate," and it was interesting to see how the pebbles carried down were constantly leaping out of the water as they struck some slight obstruction. Sometimes at a sharp angle in the run of the stream the pebbles would even leap so high as to fall into the adjoining heather. This sight was certainly an object-lesson in denudation, and brought strongly before one's mind the fact that these adamantine mountains are slowly but surely "trintling" away piecemeal to the sea.

In the "gullet" of the principal stream which comes down from a corrie-like hollow in North Goatfell, and as it nears the Rosa, the water—where the dip of the granite slabs is reduced to 15° —leaps over little cascades made by the downward outcropping of the coarse-grained granite slabs. On the north-east side of the mountain these slabs dip E. at 30°, the wide glen of the White Water (the Gaelic name of this stream appears to have been forgotten by the natives, but was probably Uisge Ban, from a large waterfall at the junction of the granite with the slate, which viewed from a distance presents a very white appearance) is much covered with vegetation, and looks like an old bay. Opposite the head of the glen, on the ridge, there is a trap dyke at least 30 feet wide.

Goatfell has a spur to the west, on which, as already remarked, the slabs lie steeply to Glen Rosa. On the top of the mountain the dip of the coarse-grained granite slabs is N.-N.-E. at the gentle angle of 10°. On the south spur, as also on the east spur, the slabs dip E. at 40°, but towards its end the dip becomes about 25°, while at the very termination it is reduced to 20° and 15°, the surfaces of the slabs being *cockled* as in many other places. As already stated the junction of the granite and the slate occurs at the fall or linn of the White Water, but it is not easily approached except in very dry weather.

In the Cnocan burn (the little hill burn), opposite the end of the

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south spur, the coarse-grained granite slabs dip S.-S.-E. at 20°, and at the old dam wall the slate lies up against the granite at an angle of 75°, but the junction itself is not seen, although the veins of fine-grained granite which ramify through the slate indicate that it is not far away. One of these veins is very instructive, as it contains pieces of slate which have been sucked by the granite into rounded form (fig. 16). The old gorge of the Cnocan burn

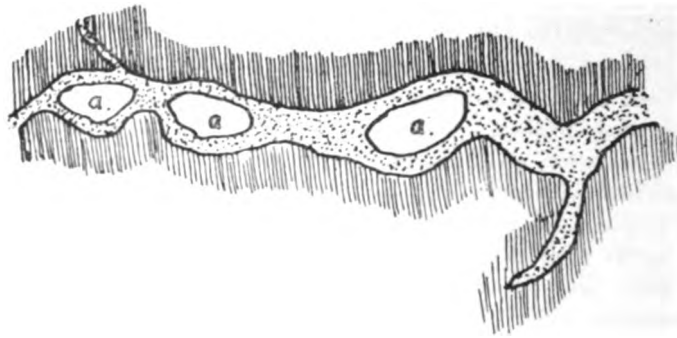

Fig. 16.
Part of a Fine-grained Granite Vein.
(*a*, *a*, *a*) Rounded Pieces of Slate in the Granite.

has been very much filled up with Boulder-clay, which, when cut through, is seen to be of considerable depth, and in some places is covered by granitic sand.

The Arran granite occupies an area of about forty-one square miles, the perimeter being sub-circular, and it is completely surrounded by a belt of slate, which is thin on the east side of the area, but of great thickness on its west side where it extends into Kilbrannan Sound. Generally speaking the slate dips away from the granite, leaning against it at angles varying from 70° to almost a perpendicular (see fig. 1, p. 218). There are, however, two marked exceptions to this, as in Glen Dubh, where the slate is perpendicular, *with its strike running end on to the granite* (fig. 17, *c*, p. 249), and in Torr Nead an Eoin, where *it dips down upon the granite* (see figs. 8 and 9, pp. 232 and 233).

That the slate has been much twisted and broken before it was invaded by the granite is very clearly shown. It was first crumpled and broken, then the cracks caused by this movement were infilled by quartz, but *not one of these quartz veins is ever seen*

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running from the slate into the granite, which shows that they had been formed long before the granite was forced up through the slate.

The quartz veins in the slate are, perhaps, nowhere better seen than they are at Imachar Point, where magnificent photographs of the gnarled old sea-stacks and cliffs could be obtained. The veins are, generally speaking, very short, sometimes lying parallel with the bedding of the slate, but also crossing the bedding at all angles. Many of the cracks now quartz-filled have clearly been

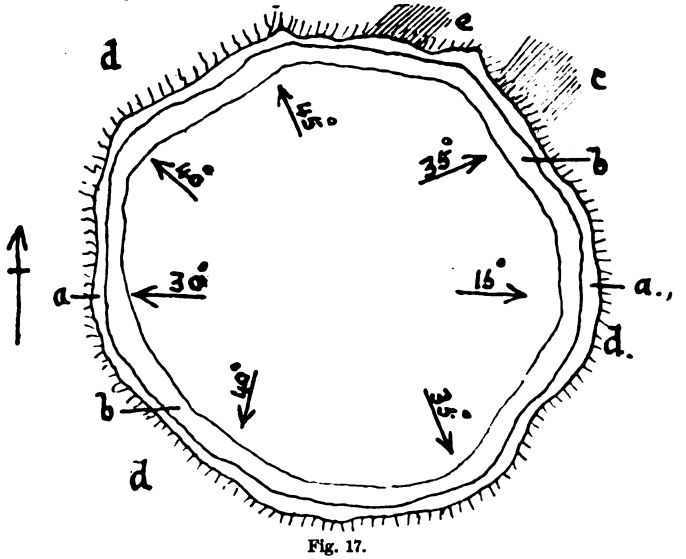

Fig. 17.

Diagram of the Granitic Area.

(*a*) Ring of Fine-grained Granite; (*b*) ring of Coarse-grained Granite, with confused jointing; (*c*) Slate on edge and end on to Granite, Glen Dubh; (*d*) Slate penetrated by Granite Veins; (*e*) Slate slanting down on Granite at Torr Nead an Eoin.

The Arrows show the Dip of the Granite Slabs *towards the Slate* all round the Granitic Area.

caused by stretching and "riving" when the slate was being thrown into folds, and we often see a short vein occupying the short bend of a fold (fig. 18, p. 250).

The slate at Imachar (the meadow) is of a pale green colour, and where washed by the sea is seen to be splendidly puckered up into minute foldings, the pressure which caused this having been applied from W.-N.-W. and E.-S.-E. Besides the quartz veins in the slate there are large rugged masses of quartz which have been

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filled into very irregular hollows. Infilled veins in rocks have generally the appearance of having been formed by a deposition on both sides of the opening, growing towards the centre, but in those under notice I found no appearances of this kind, the quartz occurring in homogeneous masses.

To the south of Whitefarland the slate is on edge, the strike running W.-S.-W., the surface being beautifully ice-polished. The striæ run parallel to Kilbrannan Sound, showing that the glacier completely filled up that hollow and moved southwards in the direction of its long axis. It is seldom one sees an ice-polished granite block in fine condition, owing to the fact that the parts which have been protected from weathering are not often exposed, but when the little mill-pond at Auchiemore (the large field) was dug a beautifully striated and polished granite block was got from the Boulder-clay.

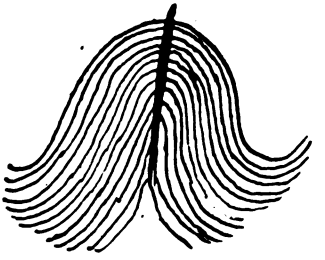

Fig. 18.
Twisted Slate; the thick line representing a Quartz Vein.

That the slate was subjected to great pressure we have other evidence than that of the folding, crumpling, and puckering, for, in the slate on the shore opposite Pirnmill school-house, there is a thick bed of coarse grit, the particles of which have been *partially flattened out by pressure*. Blocks of this grit are often seen built into dykes even towards *the east side* of the granitic area, showing that the bed is of some extent.

Along the western border of the granitic area the slate is comparatively soft and splintery, and it is difficult to get pieces of sufficient size and hardness for building; whilst in Catacol Glen, the Doire Bhuidhe, Torr Nead an Eoin, Glen Dubh, and Glenshant Rock it is hard and solid, as it also is at a distance from the granite at Coillemore (the big wood) Point.

I have already referred to the fact that between Coillemore Point, Lochranza, and Torr Nead an Eoin, the slate has been thrown into folds, some of it soft, but most of it hard (fig. 9, p. 233). Also, that no quartz veins penetrate the granite from the slate, but that, on the other hand, at every known junction fine-grained granite veins penetrate the slate, while sometimes even coarse-grained granite touches the slate and penetrates it as well.

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There is, as a rule, a narrow ring of fine-grained granite between the slate and the coarse-grained granite, and within this another wider ring of granite in which the jointing is confused (see fig. 17, *b*, p. 249). Within this confused ring the slabs, where seen, always dip towards the slate, but never at a greater angle than 50°, or, except in Catacol Glen, at a smaller angle than 30°, whilst the slate dips *from* the granite all round the granite area at 70° to 80°, except on the north and north-east (see fig. 17, *c*, *e*, p. 249).

As already remarked, the principal glens occupy synclinal troughs in the granite, the dip of the slabs in the bottoms of the glens being remarkably small—never more than 20°—except near the slate, and on the mountain summits it seldom exceeds 10°, if we except Sail Chalmadale, which is only a remaining segment of a mountain (see fig. 7, p. 231), Beinn á Chliabhain (see fig. 12, p. 239), Beinn á Chir (fig. 20), and Cir Mhor, the alteration of dip

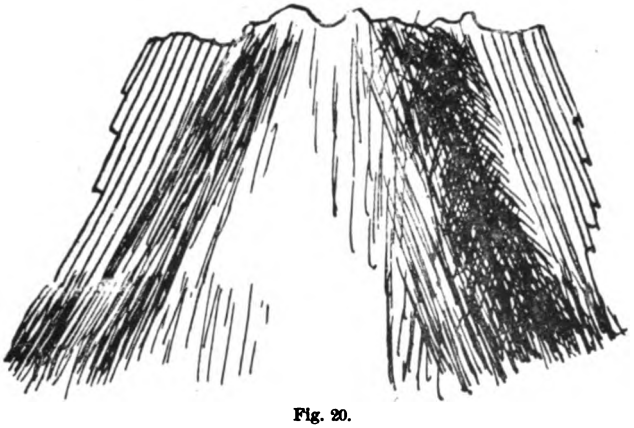

Fig. 20.
Summit of Beinn á Chir, showing the anticlinal position of the Granite Slabs.

on the three last-named being remarkably sudden and forming anticlines. The summits of the principal mountains are centres of qua-qua-versal dip, and the ridges are lines of anticlinal bends.

At many points we have seen that the all but universal slab-like nature of the granite gives place to large tabular masses, where the dividing planes can only be traced for a few feet till they *break band* with another mass. Where the granite is slab-like, the slabs vary from about an inch up to, perhaps, 20 feet in

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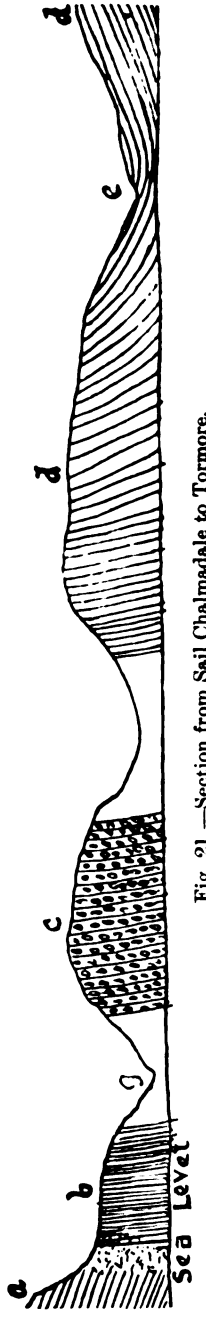

Fig. 21.—Section from Sail Chalmadale to Tormore.
(*a*) Granite; (*b*) Slate; (*g*) Torsa Valley; (*c*) Conglomerate; (*d, d*) Red Sandstone; (*e*) Machrie Water in Syncline.

thickness, and nearly all of it, fine-, medium-, and coarse-grained, *contains numerous little cavities.*

From the way in which the granite is —generally speaking—fine-grained at its junction with the slate, it has been concluded by previous writers that the granite began to cool from a fluid condition, and solidify against the slate; but from the way in which *the granite slabs everywhere dip towards the slate* (see fig. 17, p. 249), I think this idea cannot for a moment be entertained. If it had cooled in this manner *the slabs ought to have been parallel to the slate*, but they are not so at any part.

On the contrary, this fine-grained granite ring, together with the fine-grained veins penetrating the slate, is evidently the result of a re-melt of the outer boundary of the nucleus from excessive friction, when it was being forced up bodily as a solid mass through the slate. The friction between the granite and the slate must have been so great at this period, that a portion of both was fused, the fused material penetrating the cracks then made in the slate, and the rapid cooling causing it to be fine-grained. When this took place—after the Carboniferous period—there was great uptilting of the neighbouring formations on the shoulders of the granite, as a section from Sail Chalmadale to Tormore (the big hill), a distance of 4 miles, will show (fig. 21).

We now come to an explanation of the slab-like nature of the granite, which has at one time been in a state of great fluidity. It contains no enclosures, such as pieces of unfused stratified rock (except

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to a small extent next the slate), as we find in other granites, like that of Loch Doon in Ayrshire, where nearly every boulder derived from the granite contains its piece or pieces of unmelted sedimentary rock. It contains numerous gas-cavities bristling with crystals, which would seem to indicate that *it cooled under much less pressure than it originated under.* It is curious to note that these cavities are always empty, so we are forced to the conclusion that there has been no circulation of water through the granite, carrying silica, lime, &c., in solution, and leaving them by deposition or crystallization in the cavities.

There is no gneiss or mica-schist between the granite and the slate, so that, taking the presence of the gas-cavities combined with this fact, it appears evident that the granite was at one time probably injected as a large fluid laccolite between the mica-schist and the slate (or it may have been a product of the fusion of gneiss, mica-schist, and part of the slate, from pressure, after the latter had been thrown into large folds. I, however, favour the former theory). It is now well known that granite has sometimes been injected between rock-masses of various ages.*

Leaving out the confusedly-jointed ring of granite near the slate, it is very probable that the small areas where the granite assumes the tabular structure, and which have often already been noted, were at one time, in all probability, the deep-seated roots of volcanic funnels, and that the ash-beds interlaminated with the Carboniferous strata may be the *tail-ends* of showers which were sent out from volcanoes situated far above the molten granite below.

When the granite began to cool it would at first solidify, or partly solidify, next the folded slate above it. At every volcanic eruption there would be a movement in the liquid granite (I use this term for convenience sake) which would cause it to flow along under the portion which had already so far hardened. Such an underground and inverted *igneous stratification* (if I may be allowed the expression) would cause a *divisional plane* to be formed; solidification would again go on until another eruption took place, when another divisional plane would be produced; and a sufficient repetition of the process would form all the slabs, a short period between eruptions giving time for thin slabs only, and longer

* Prestwich's "Manual," part 1st, pp. 220, 221, 243, and part 2nd, p. 20.

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periods allowing for thicker slabs, while the action of the well-known law that igneous rocks break up into pieces of greater or lesser size would produce all the other divisional appearances, even the wedge-like blocks which the granite often exhibits.

We have already seen that there are no secondary deposits between the joints of the granite slabs, owing, perhaps, to the great pressure under which the rock solidified, which would prevent the joints from opening as they have done in many varieties of trap rock.

It is even possible, and indeed very probable, that the granite slabs, while still red-hot, were considerably increased in dip as the rock first began to be moved upwards; but a time would come when this ceased, and when the granite was quietly but forcibly squeezed up through the slate, turning it up on edge, or shearing up through it, as at the north side of the granitic area. It was during this period of its history that the surrounding zone of fine-grained granite was formed by re-melting from excessive friction, and the contained belt of confusedly-jointed rock was produced by the granite being crushed, and the individuality of the slabs destroyed (see fig. 17, p. 249).

The power—lateral compression—which raised the Arran granite as a solid mass, was but a very small fraction of that which affected the West of Ireland and a large part of Scotland and Norway.

This crushed belt in the granite, extending from Glen Scaftigill, by the china clay "gullets," into Glen Gebhin, and probably as far as Torr Nead an Eoin, may either have been formed at this time, or at a later period, when the faults, which shifted the fine-grained granite veins cutting through the slate, were formed; and in all probability the trap and pitchstone dykes were filled from below into cracks produced when the granite was undergoing upheaval as a solid nucleus, though there may have been a considerable lapse of time between the production of the different varieties of dykes.

Although at a high angle the granite is everywhere seen to run under the slate, none of the latter, originally lifted up with the granite, being found to remain resting upon it, except at Torr Nead an Eoin. At Lochranza the granite is probably at no great depth below the slate.

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That *the slate filled the glens to a considerable extent at one time*, I think there can be no doubt, though many writers would have us believe that the glens were entirely carved out of the granite. I, on the other hand, think they were in great measure carved out of the slate folds on which the granite slabs were at first moulded.

In making a traverse from Beinn Bharrain to Goatfell, a distance of seven miles, four anticlinal folds and three synclinal folds in the granite are passed over (as will be seen from the diagrammatic section, fig. 22).

It appears to me, then, that the slabs of the Arran granite never were in a horizontal position, but were originally moulded on the folds of the slate. Their dip may, however, have been considerably altered by subsequent movements after the granite had consolidated, and the fact that the granite slabs inside of the ring of confused jointing *always dip towards the slate*, I take to be an indication of such movements, clearly showing that the slabs at the perimeter of the granitic area were dragged down (relatively speaking) by friction when the granite was being pushed up through the slate. The slate and the rocks beyond it at that period were greatly increased in dip, the divisional joint between

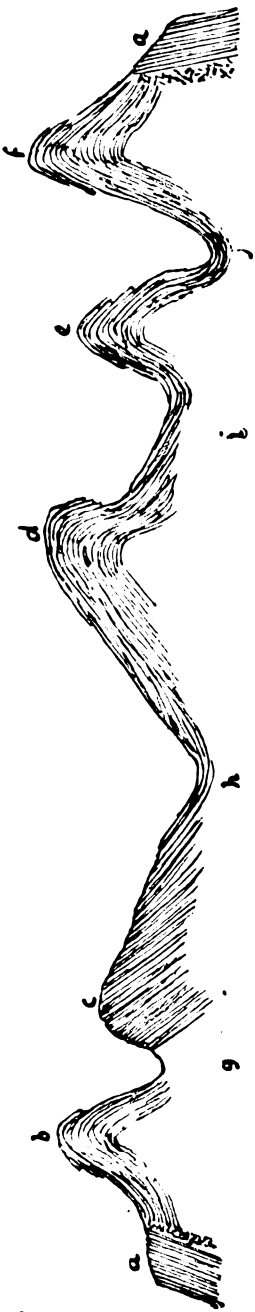

Fig. 22.—Diagrammatic Section across the Granitic Area from Beinn Bharrain to Goatfell—from west to east.
(*a, a*) Slate; (*b*) Beinn Bharrain (anticlinal fold); (*c*) Sail Chalmadale (the Slabs all dip to N.-E.; (*d*) Beinn Nuis (anticlinal fold); (*e*) Beinn a Chliabhain (anticlinal fold); (*f*) Goatfell (anticlinal fold); (*g*) Glen Sceftigill (crushed Granite); (*h*) Iorsa Valley (synclinal fold); (*i*) Garbh Allt Valley (synclinal fold); (*j*) Glen Rosa (synclinal fold).

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the granite and the slate being a sub-circular fault of great throw, and the ring of fine-grained granite next the slate having been then formed by friction, as already explained.

Note.—At page 285 of the Report of the Director-General of the Geological Survey (1894) there occurs the following statement:—"The granite of the northern half of Arran has been shown to possess so many petrographical resemblances to the granophyres of the Inner Hebrides, and to the granites and granophyres of the Mourne Mountains and Carlingford in Ireland, that geologists are now quite disposed to regard it as of Tertiary age. Their inclination to place it in so late a geological period will be considerably strengthened by the evidence now adduced as to the Permian age of the newer red sandstone and marls of the island."

The evidence here referred to is the discovery by Mr. James Thomson, F.G.S., of pebbles of Carboniferous fossiliferous limestone in these red sandstones. This fact shows two things—(1) That the Carboniferous rocks had been elevated and partially denuded before these sandstones were laid down; (2) That the sandstones had been tilted, probably by the upheaving of the solid granite, but that the latter had not then been exposed, as there are no granite pebbles in the sandstone.

This, of course, does not affect the author's argument that the granite slabs may have at first been moulded on the folds of the slate.

It may be of interest to geologists who visit the island to know that, in the author's estimation, the best point of view of the Arran Granite Mountains is to be got from the Slate hill situated between the Garbh Allt and Glen Shurig, which is easily reached by following the String road up to the col, and then proceeding over the moor.

March, 1896.

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No. XXIII.—Charred Coal, with Graphite, and Discovery of Diamonds in the Graphite at Craigman, New Cumnock. By John Smith.

[Read 10th January, 1895.]

The notice of the Parish of New Cumnock, Ayrshire, in the *New Statistical Account of Scotland*, vol. v., p. 514, has a contribution "by a gentleman who has given much attention to the subject" [of Geology, but who is not named]. It contains the following relating to the Craigman Mine:—

"In the coal formation at Craigman, plumbago or black-lead occurs, and has been wrought for a long period. The plumbago here appears to be formed by basaltic rocks coming in contact with a seam of 6 to 8 feet of columnar coal. In examining this mine, the whole process of the conversion of the coal into plumbago is evidently from volcanic agency. The basalt, when in a state of fusion, bursting up through the coal metals and mixing with the coal, has charred or "*dandered*" the coal, and also converted it into plumbago. The seam of coal, when nearly in contact with the basalt, is completely charred for 10 or 20 yards, in different degrees of hardness, as it approaches nearer the basalt. The plumbago is found in irregular masses, imbedded in the basalt, and has often the same columnar structure as the coal. A further proof of the volcanic action is a bed of slate-clay which forms the roof of the coal, and when in contact with the basalt is raised up unbroken, and converted into a silicious substance, like porcelain jasper; and in the section of the rocks at the entrance to the mine a piece of this jasper, about 2 feet long and 6 or 8 inches thick, has sunk down several feet into the basalt, which must have occurred when the basalt was in a state of fusion."

The Craigman Graphite Mine, said by popular report to have been worked for about a hundred years, was abandoned about 1848, but, so far as I could learn, not because the material was exhausted. I examined it on 25th December, 1894.

The section to be seen at its mouth is as follows:—

	Ft.	In.
Sandstone, coarse-grained, under Boulder-clay, hardened and shivery,...	4	0

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	Ft.	In.
Porcelanized shale, light-coloured for 3 or 4 inches next the sandstone, ...	0	11
Hard shale, bluish-coloured, and breaking up into small fragments, ...	0	11
Porcelanized shale, bluish-coloured, ...	3	1
Trap, decomposing, and with hard *porphyritic* balls, *onion-coated*, ...	6	4
Trap, solid, coarsely crystalline, ...	5	0
	20	3

The mine is situated below the *solid* trap, and is from 6 to 8 feet high. I have examined nearly every accessible part of it, and as far as I could see the trap had invaded the coal-bed in such a way as to leave the burnt coal in detached patches, the *smaller* of which had been converted into graphite; but, of course, one should have been conversant with the mine in a working condition to have satisfied himself perfectly on this point.

There appear to be but few patches where columnar structure has not been developed in the coal, and the columns lie in every possible direction, being often considerably curved, and their size seldom less than $\frac{1}{8}$-inch, or more than 1 inch, in diameter. *The columns often lie nearly parallel to the trap*, and there is generally a thin layer of massive graphite *close above it.*

In the mine I did not see a single bit of *hard trap*, and no doubt its absence would greatly facilitate the working of the graphite. In many instances where it comes into contact with coal, trap becomes *white*, but in this mine I did not see any massive white trap, though in some of my polished specimens I found small pieces *enclosed in the graphite.*

About half an inch of graphite is soldered to the trap, and here there is a *parting* in the mineral, the surface of which presents us with a series of raised wavy lines.

In some pieces which I have polished, the graphite is seen running through the charred portion of the coal in narrow ramifying strings (the end sections, of course, of thin plates); and even in the graphite itself there are *strings* which are far brighter, when polished, than ordinary graphite. Some portions show narrow alternating parallel layers of *graphite* and *charred coal.* These layers average about $\frac{1}{8}$-millimetre in width, and are possibly the lines of growth of some kind of wood. This fact shows us that different *qualities* of the coal may be converted into the very

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different substances—coke and graphite—*under the very same conditions* as to temperature and pressure. It would not be possible to have a better illustration of this than the present one, seeing the layers are in such close alternate juxtaposition.

In the pure graphite polished surfaces shine with the well-known smooth homogeneous lustre of a blackened and polished grate, for plumbago, black lead, wed, and graphite are just the same chemical substance. Small blebs of the trap enclosed in the graphite indicate that the latter must have been in a state of fusion; and it is sometimes penetrated by interlacing strings of the graphite, some of which have a *gnarled* structure, such as may be seen in polished sections of a tree-knot. Where strings of the graphite occur they always appear to be quite pure, *i.e.*, without admixture of charred coal, which never appears in strings. Some fractured surfaces of the charred coal are very brilliant. It is often quite porous, and the walls of the hollow cavities generally glitter, but I have seen no instance where they have been filled with secondary deposit. The pure graphite, on the other hand, is dull in fracture, apparently perfectly solid, and leaves a mark on paper like that made by an H.B., or some of it like an H.H.B., pencil.

Where the coal is only *charred* it is often quite *brittle*, and the columns generally fall apart when pieces are dug out; but the columns of the graphite are soldered more firmly together. The only reason I can assign for the coal having taken the graphitic form is that it has, generally speaking, been subjected to a *higher heat* than the merely charred portion, and this because it has been in smaller patches.

The coarsely crystalline and even porphyritic nature of the trap shows that it has cooled very slowly, which was probably owing to the thick bed of fine-grained shale—now porcelanized—allowing the heat to radiate off from it but slowly, and perhaps the strata at this particular part of the coal-field may have been heated up to an extra degree by molten trap flowing between the beds for some time before the last of it finally consolidated. Of course, where trap has been injected between strata, such an effect must always have been produced, but in this case it may have been to a greater degree than in many other instances I have noted in Ayrshire (the land of burnt coal), and elsewhere. It is also very probable that the 5-feet bed of solid trap was injected at a later

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period, perhaps whilst the rest of the trap was in a heated state. At the same time, had the shale-bed above the coal—now seen above the trap as baked-shale—been thinner, or absent altogether, we may be certain that, although the coal would have been charred, none of it would have been converted into graphite. What kind of rock is below the level of the mine I had no opportunity of ascertaining, but it is, most probably, trap, as a considerable outcrop of that rock occurs on the hill beyond the outcrop of the coal-bed.

The graphite is, of course, not always pure, and in many instances it is considerably mixed with the charred coal. When rubbed down on fine-grained sandstone, or "Water of Ayr" stone, with water, a small shining film of it collects on the surface of the water. The porcelanized shale breaks up into little tabular blocks, but only at certain places will it part along the bedding. Some of it is identical to Lydian stone. A small trap dyke cuts through it and the sandstone.

The Craigman Mine is situated about 800 feet above sea-level, and five miles W.-S.-W. of New Cumnock. Many parts of the walls of the mine are quite rust-coloured from a deposit of hydrated iron oxide, and at some places they are coated with wax-like sheets of stalagmite; but these features have been impressed subsequent to the driving of the mines. The people of the neighbourhood state that the Craigman graphite was of very fine quality, most of it having been carted into England, as there was then no railway. The proposed Muirkirk and Dalmellington line, in all likehood—if made, as certainly it should—will pass the mine-mouth, in which case the Craigman graphite will probably again be worked.

The "leads" of writing pencils are sawn directly from blocks of native graphite, when it is found to be pure and firm enough, the quality of the pencil depending, of course, in such a case, on that of the graphite. But nowadays, "graphite" for pencils is often an artificial admixture of that substance with various qualities of carbon, the materials being ground together and rendered solid by great pressure and impact; in this way "leads" of any degree of blackness and hardness can be produced. The *reporter's pencil* appears to have in addition to the above materials some kind of lubricant, such as steatite (soap-stone), or talc, which renders it almost frictionless. The impurities of graphite range from 5 to 40 per cent.

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In Ayrshire, besides at Craigman, graphite has been found in the coal formation at Hurlford, a sample of which, in the Hunterian Museum, Dr. Young, F.G.S., brought under my notice; and the writer of "The New Statistical Account" of Kilbirnie Parish says that "a vein of graphite or black-lead is intersected by the stream which divides this parish from that of Dalry." In the Highlands of Scotland graphite occurs in small nests in gneissose rocks, in all likelihood the highly-metamorphosed remnants of coal-beds, and in the Island of Mull small quantities of it are to be found in rocks which are probably of mesozoic age. The Borrowdale Mine in Cumberland was long famous for the fine quality of its *pencil-graphite*, which was worked in connection with trap in the clay-slate formation.

Abroad, graphite is found in Greenland, Canada, the United States, Scandinavia, the Ural Mountains, Germany, Siberia, &c., and at the present time large imports of it are made from Ceylon and Travancore, this quality of graphite closely resembling the bright, scaley material got from the old hearths of blast furnaces.

Professor Nicholson says ("Ancient Life History of the Earth," page 36)—"In the Huronian [formation] at Steel River, on the north shore of Lake Superior, there exists a bed of carbonaceous matter which is regularly interstratified with the surrounding rocks, and has a thickness of from 30 to 40 feet. This bed is shown by analysis to contain about 50 per cent. of carbon, partly in the form of graphite, partly in the form of anthracite; and there can be little doubt but that it is really a stratum of 'metamorphic coal.'" And again at page 68, "The Laurentian Rocks [of Canada] contain a vast amount of carbon in the form of black-lead or *graphite*. This mineral is especially abundant in the limestones, occurring in regular beds, in veins or strings, or disseminated through the body of the limestone in the shape of crystals, scales, or irregular masses. The amount of graphite in some parts of the Lower Laurentian is so great that it has been calculated as equal to the quantity of carbon present in an equal thickness of the coal-measures. The general source of solid carbon in the crust of the earth is, however, plant life; and it seems impossible to account for the Laurentian graphite, except upon the supposition that it is metamorphosed vegetable matter."

Much graphite—besides what is employed in lubricating blast

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engine cylinders, polishing grates, &c.—is used in the manufacture of crucibles and "glass pots," in which case it is mixed with fire-clay, sometimes with the addition of a little iron oxide, silicious sand, and magnesia. It is sometimes used as a polishing material.

At a very high temperature, graphite can be artificially produced, when it appears as bright, flexible, scaley crystals, sometimes so thin as to float in the air, and the clothing of blast furnacemen is often covered with these scales, which "skinkle" [sparkle] in the sunshine like diamonds. In this form it is known as "keesh." The crystalline form of graphite is that of a thin hexagon.

Although called black-*lead*, not a particle of lead enters into the composition of graphite. This is probably a transference name, as writing pencils, before the invention of black-lead pencils, used to be made of the *metal* lead.

It may be interesting to note that diamonds heated in a closed crucible to a temperature of melting cast iron, remain *unchanged;* but when the temperature is increased to that of melting malleable iron, the diamonds are changed into a black coke, or, as some say, into graphite. Bone-charcoal dissolved in molten silver at a temperature of melting steel is converted into *minute diamonds* and graphite. Carbon, when in the nature of a diamond, crystallizes in the form of a cube.

In the Craigman Mine, the graphite close on the trap contains minute particles which scratch rock-crystal, so that these particles are doubtless SMALL DIAMONDS, and this is the first time, so far as I know, that diamonds have been chronicled as having been found in the British Isles!

When this graphite is reduced to a fine powder, and examined by the microscope in a good light, some of the dust particles are seen to emit bright flashes as if they were on fire, the light being decomposed into the different colours of the rainbow.

From what is known as to the artificial production of diamonds, it is probable that this part of the coal-bed may have been raised to the temperature of *melting steel*, but in speculating on this point the unknown element of *pressure* must always be taken into consideration.

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No. XXIV.—Boulder-clay, a Marine Deposit. By Joseph Wright, F.G.S. Part First.

[Read 13th December, 1894.]

Before referring to the Boulder-clay of Scotland it will be well to consider similar deposits on the other side of the channel in the north-eastern portion of Ireland, where they have for many years been the object of careful investigation by local geologists.

Boulder-clay as it occurs in Ireland may be described as a hard tough compact clay in which boulders, large and small, and clay, are mixed together in a confused unstratified mass. The boulders and stones usually have their angles more or less worn off, the surfaces being frequently smoothed and marked with grooves and striæ. By far the greater portion of the stones are of local origin, but a considerable number have been transported from a distance. The underlying rocks on which the Boulder-clay rests are invariably eroded, and bear striæ which tell of ice moving over them from the north, north-east, or more rarely north-west, the stones in the clay also indicating a similar movement, their origin being almost invariably from sources further north. This clay forms the subsoil of most of the district referred to, as also that of the greater portion of the British Isles. It is found covering both the hillsides and the valleys, but is best seen along the margins of the glens where the rivers and the streams have cut through it, exposing sections, or where artificial cuttings have been made in quarries, railways, borings, and other works. The excavations made some fifty years ago for the Belfast Water-works gave the opportunity of finding a greater number of shells from the Boulder-clay than has ever been met with at any other locality.

So long ago as 1843 General Portlock* recorded the occurrence of shells in the North of Ireland Boulder-clay, and drew the inference that it is a marine sedimentary deposit. The same conclusion was arrived at by Mr. S. A. Stewart,† F.B.S.E., who worked the beds zealously, and in the year 1880 published "A Report on the Mollusca of the Boulder-clay of the North-east of Ireland," in which he enumerated 69 different species.

Although so many shells have been recorded, it must not be

* "Report on the Geology of Londonderry," &c., pp. 738-740.

† *Proc. Belfast Nat. Field Club*—Appendix, 1879-80, pp. 165-176.

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inferred that they are common in the Boulder-clay. Molluscan shells are as a rule very rare and are only to be found by patient searching. Occasionally perfect specimens are got, though they are much more usually in a fragmentary condition; but the occurrence of such fragile bivalve shells as *Leda pygmæa* and *L. minuta*, obtained by Mr. Stewart with their valves united, shows that they must have lived on the spot where they were found. Although the fauna of the Boulder-clay is not rich, it is nevertheless a marine fauna having a boreal facies, the shells unquestionably belonging to the deposit, and not having been either drifted from a distance or derived from an older bed.

At the time that Mr. Stewart was examining the clays for Mollusca, I was examining them microscopically for the minuter forms, and when his paper appeared I published a report on the Foraminifera which I had found.* In all the clays where he found molluscan shells I found Foraminifera, and I also got them at places where no shells had been met with. With very few exceptions these tiny rhizopods were met with in such of the clays as I examined, the specimens being usually in the finest preservation as if just brought up by the dredge from a recent sea-bottom, and I am satisfied they must have lived on the spots where they are now found.

Since then I have examined Boulder-clays from a number of other localities, and with a few exceptions have found Foraminifera in every one of them. Usually the organisms were rare, but at some places they were most abundant. For instance, I may mention that in a packet of Boulder-clay about five pounds weight lately sent me by Miss Thompson of Macedon, from a boring made by the Belfast Water Commissioners, near Corrigan Bridge, Mourne Mountains, County Down, I found 37 different species of Foraminifera, the actual number of specimens being about 2300. *Nonionina depressula* and *Polystomella striato-punctata* were in much the greatest profusion, and numbered jointly about 2000 specimens. These two species are the most characteristic and abundant Foraminifera of the Boulder-clay. *Cassidulina crassa*, although not so abundant, has been met with in nearly all the gatherings. *Bolivina plicata*, *Globigerina bulloides*, and *Rotalia Beccarii* are also plentiful. These, as well as nearly all the other Foraminifera

* *Op. cit.*—Appendix, 1879-80, pp. 149-163.

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found in the Boulder-clay, are now to be met with living almost everywhere around our coast, at moderate depths, in quiet water, and where the bottom is muddy, and we may presume that the microzoa of the Boulder-clay lived under somewhat similar conditions.

That the molluscan shells are usually broken, and that the Foraminifera are less abundant than they are at present in our seas, is not surprising, when we consider the severity of the climate which must have prevailed at the period when they lived—the constant dropping of boulders from icebergs, as well as the perpetual movement and crushing of shore-ice must have largely contributed to this result. In most instances the Foraminifera in the Boulder-clay are smaller in size than those now found living off our coasts, this also no doubt being largely due to the same factor that caused their comparative scarcity.

As already stated the rocks underlying the Boulder-clay are invariably eroded. This must have been done by moving ice, as shore-ice, and icebergs, and in part by glaciers. Subsequently the land became submerged, and it was during this period that the Boulder-clay was deposited, the mud, gravel, and boulders being due to droppings from icebergs, assisted by mud and stones brought down to the sea by land-ice.

The close proximity of the south-western portion of Scotland to the north-eastern part of Ireland inclined me to consider it not improbable that the Boulder-clay at both places might have been deposited under somewhat similar conditions. For this reason I had long wished for an opportunity of microscopically examining Scottish Boulder-clay. On expressing this wish to Mr. James Neilson, one of your members, he at once, in the kindest manner, offered to get me some packets of the clay. I have since from time to time received from him five samples from different localities averaging in weight about five pounds each, and in all of these I have found Foraminifera. These are all of marine types, and I do not remember ever finding a brackish-water Foraminifer in Boulder-clay.

In washing and cleaning these specimens for microscopical examination the process I adopted was the same as that which I have always used in washing such clays, viz., taking floatings from it, and it was these alone which I examined. For

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the information of geologists who may desire to try the work I subjoin the following particulars as to my method of taking floatings. It is the plan usually adopted by naturalists looking for microzoa in dredgings from off the coast, or in shore gatherings, and the same process may also be used with advantage in the case of Post-tertiary clays and gravels. No doubt some of the specimens are liable to be lost, but on the whole it gives good results. Four or five pounds weight of clay will usually yield only a few grains of floatings, so that the time spent on floating and cleaning is more than compensated for by the small quantity of material which remains to be examined. The clay should first be carefully dried, then immersed in water till it falls down into the condition of mud, when it should be washed through a fine sieve, and again dried. It should next be placed in a deep vessel of water, and stirred for a minute or two. On becoming quiescent the mud and sand rapidly fall to the bottom, whilst the Foraminifera, having their chambers filled with air, rise to the surface; this floating should be gently poured off into a fine sieve. By repeating the process two or three times all the floatings will be secured, and on being dried they will be ready for examination. It frequently happens that the clay contains vegetable matter which rises to the surface with the floatings. When such is the case the floatings should be boiled in a little water with a stick of caustic potash. The result of this treatment is the reverse of the preceding process, as the Foraminifera, becoming filled with water, fall to the bottom, whilst the vegetable matter, being more or less dissolved by the potash, comes to the surface and can be readily removed. The residue should be re-boiled a few times in fresh water to get rid of the potash, which would otherwise crystallize on the specimens and spoil them.

The following is a list of the Foraminifera I have found in the specimens of Boulder-clay sent me by Mr. Neilson, with the localities from which the clay was taken:—

Huntershill Quarry, Bishopbriggs; 8 specimens.

Bulimina marginata, d'Orb., rare.
Lagena Orbignyana (Seg.), very rare.
Discorbina globularis (d'Orb.), rare.
Globigerina bulloides, d'Orb., rare.
Nonionina depressula (W. & J.), very rare.

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Provanmill, Railway Cutting, 3 miles N.-E. of Glasgow; 7 specimens.

Miliolina seminulum (Linn.), very rare.
Bulimina marginata, d'Orb., very rare.
Globigerina bulloides, d'Orb., very rare.
Rotalia Beccarii (Linn.), very rare.
Polystomella crispa (Linn.), very rare.
Polystomella striato-punctata (F. & M.), rare.

Hamilton Hill, Brickworks, N.-W. of Glasgow; about 100 specns.

Miliolina seminulum (Linn.), frequent.
Haplophragmium Canariense (d'Orb.), very rare.
Bulimina pupoides, d'Orb., very rare.
Bulimina marginata, d'Orb., very rare.
Bolivina dilatata, Rss., very rare.
Cassidulina lævigata, d'Orb., very rare.
Lagena lævis (Mont.), very rare.
Lagena lucida (Will.), very rare.
Uvigerina angulosa, Will., very rare.
Globigerina bulloides, d'Orb., rare.
Truncatulina lobatula (W. & J.), very rare.
Rotalia Beccarii (Linn.), very common.
Polystomella crispa (Linn.), rare.
Polystomella striato-punctata (F. & M.), very common.
Nonionina depressula (W. & J.), very common.

Braeside Street, Garscube Road, in the N.-W. of Glasgow; 20 specimens.

Bolivina plicata, d'Orb., very rare.
Pulvinulina Patagonica, d'Orb., very rare.
Globigerina bulloides, d'Orb., rare.
Rotalia Beccarii (Linn.), common.
Nonionina depressula (W. & J.), common.
Polystomella striato-punctata (F. & M.), frequent.

Craigpark, opposite Regent Place Church, Dennistoun, Glasgow; 2 specimens.

Globigerina bulloides, d'Orb., very rare.
Truncatulina lobatula (W. & J.), very rare.

LIST OF LOCALITIES.	Number of Foraminifera found.
Hunter's Hill, (Laminated Clay), -	8
Hunter's Hill, - - -	
Provanmill, - - - - -	7
Hamilton Hill, - - - -	In 2½ lbs.—about 100.
Braeside Street, - - - -	20
Craigpark, - - - - -	2

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TABLE SHOWING THE DISTRIBUTION OF THE FORAMINIFERA IN THE BOULDER-CLAY OF THE GLASGOW DISTRICT.

Abbreviations: r, rare; vr, very rare; c, common; vc, very common.

LIST OF SPECIES.	Hunter's Hill, (Laminated Clay).	Hunter's Hill.	Provanmill.	Hamilton Hill.	Braeside Street.	Craigpark.
Bulimina marginata, d'Orb.		r	vr	vr		
,, *pupoides*, d'Orb.				vr		
Bolivina dilitata, Rss.				vr		
,, *plicata*, d'Orb.					vr	
Cassidulina lævigata, d'Orb.				vr		
Discorbina globularis, d'Orb.		r				
Globigerina bulloides, d'Orb.	r		vr	r	r	vr
Lagena Orbignyana. Sig.		vr				
,, *lævis*, Mont.				vr		
,, *lucida*, Will.				vr		
Miliolina seminulum, Linn.			vr	freq		
Haplophragmium canariense, d'Orb.				vr		
Nonionina depressula, W. & J.	vr			vc	c	
Polystomella crispa, Linn.			vr	r		
,, *striato-punctatella*, F. & M.			r	vc	fr	
Pullinia spheroides, d'Orb.				vr		
Rotalia Beccarii, Linn.			vr	vc	c	
Pulvinulina Patagonica, d'Orb.					vr	
Truncatulina lobatula, W. & J.					vr	vr
Uvigerina angulosa, Will.					vr	

A good many specimens of Malacostraca were found in the different packets of clay, but they have not yet been identified.

The Foraminifera of the Boulder-clay of Scotland are as perfect and as fresh-looking as those found in the Boulder-clay of Ireland, and are on the whole very similar to them. They are as yet, however, as might be expected, much fewer in number, on account of the small quantity of clay microscopically examined, seventy-five species having been found in the Irish clays. Some of those from the Scottish clays attain finer proportions than they do in the Irish deposits. This is notably the case with *Globigerina bulloides* and *Rotalia Beccarii*, the Irish specimens being usually very small in size. *Cassidulina crassa*, a somewhat common form in Ireland, was not met with in the Scottish clays. A young specimen of *Polystomella crispa* from Hamilton Hill was ornamented with long delicate spines in the finest preservation.

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I may also add that I recently received from Mr. John Stears, of Hull, a packet of Boulder-clay from that locality. This English clay was also found to contain Foraminifera as follows:—

Bolivina dilatata, Rss., very rare.
Cassidulina crassa, d'Orb., frequent.
Lagena sulcata (W. & J.), very rare.
Lagena squamosa (Mont.), very rare.
Polymorphina lactea (W. & J.), very rare.
Rotalia Beccarii (Linn.), very rare.
Nonionina depressula (W. & J.), frequent.
Nonionina turgida (Will.), very rare.
Polystomella striato-punctata (F. & M.), frequent.

The results which my examinations show are interesting on account of the common occurrence of these marine microzoa, most English and Scottish geologists having been of the opinion that Boulder-clay is the result of the action of land-ice, and that it is not of marine origin. I am forced to the conclusion that the Scottish as well as the Irish Boulder-clay is a true marine sedimentary deposit.

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No. XXV.—Boulder-clay, a Marine Deposit. By Joseph Wright, F.G.S. Part Second.

[Read 30th May, 1895.]

Since my previous communication to the Society in December of last year, I received from time to time from Mr. James Neilson further supplies of the Boulder-clay from the vicinity of Glasgow, for microscopical examination. They numbered in all eleven packets, five being from localities not previously examined. Before examining these clays I divided each of the parcels into two and treated them separately, which was done as a precaution against risk of accident. For want of time I have been unable to get through all the material sent; half of the clay from Hamilton Hill, west corner, and middle of quarry, also that from Shawlands, remains to be examined. I have also a packet from Robroyston not yet looked at. About ninety pounds weight of Boulder-clay from ten different localities in the neighbourhood of Glasgow has now been investigated, and in each specimen Foraminifera have been found.

They appear, however, to be very irregularly distributed throughout the clay; for instance, in a sample from Hamilton Hill, five pounds in weight, which was divided into two parts, each examined separately, the first yielded a hundred specimens and the other only two. At this spot the Foraminifera were far more plentiful than at any of the other stations, as many specimens being found as at all the other places put together. Two other gatherings taken from this quarry gave rather poor results; in one from the west corner only a single specimen was obtained, and in the other, from the middle of the quarry, only three. At Giffnock from one sample only one specimen was obtained, whilst from another there were twenty-one. At Braeside in one sample four specimens were found, and in another twenty.

All the Foraminifera which I have obtained from the Scotch Boulder-clay are referable to species which at the present time are to be found in shallow water off our coasts. *Rotalia Beccarii*, *Nonionina depressula*, and *Polystomella striato-punctata*, are the most plentiful in the clay, and these species are also amongst the most abundant of our shallow-water Foraminifera. *Globigerina bulloides* is also common, and this pelagic form is now to be met

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with almost everywhere off our coast, from abyssal depths to shallow water. A single specimen of *Discorbina parisiensis* was got at Giffnock. As a recent species it is very rare, and has hitherto only been met with at two or three localities. In the dredgings recently taken off the south-west coast of Ireland in the S.S. "Lord Bandon," it was found fairly plentiful in Valentia Harbour, at a depth of four to five fathoms. A single specimen of *Textularia globulosa* was found at Hogganfield Loch. This species is common in chalk powder often met with in hollow flints in the hardened chalk of the north-east of Ireland, and the specimen referred to may possibly have been derived from that source. It has also been met with as a recent species at a few places off our coasts, and it has been recorded from glacial clays both in Britain and in Denmark.

All the species found in the Boulder-clay of Scotland have been met with in the glacial clays of Ireland, with the exception of *Discorbina parisiensis*, recorded by Dr. Madsen* from the clays of Denmark, where he has also found most of the other species.

To my friends Mr. James Neilson and Mr. J. B. Wise I am laid under great obligation for the very valuable assistance they have rendered in supplying me with so many specimens of typical Lower Boulder-clay for examination, and it is entirely due to their taking so much trouble that I have been enabled to give such full particulars.

These clays have since been examined, and the following is the result of what was found in them:—

Hamilton Hill, west corner, 4 lbs. weight; 1 specimen.
Nonionina depressula (W. & J.).

Hamilton Hill, middle of quarry, 4 lbs. weight; 2 specimens.
Nonionina depressula (W. & J.).
Polystomella striato-punctata (F. & M.).

Robroyston, 6 lbs. weight; 1 specimen.
Bolivina lævigata (Will).

I also examined a packet of Boulder-clay, $2\frac{3}{4}$ lbs. weight, from Seven Acres, Kilwinning, which I afterwards received from Mr. John Smith, and in this I found no Foraminifera; but I consider the quantity of clay was too small to give satisfactory results.

* Middelelser Fra Dansk Geologisk Forening, 1895.

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LOCALITIES: WEIGHT OF CLAY, AND NUMBER OF FORAMINIFERA.

LOCALITIES.	Quantity of Material examined.	Foraminifera found.
Giffnock, 1st gathering,	5 lbs. 6 oz.	1
,, 2nd gathering,	5 lbs. 8 oz.	22
Helensvale, 1st gathering,	5 lbs.	1
,, 2nd gathering,	7 lbs.	7
Braeside Street,	6 lbs. 4 oz.	4
Hamilton Hill,	2 lbs. 4 oz.	2
,, ,, west corner,	3 lbs. 12 oz.	1
,, ,, middle of quarry,	3 lbs. 12 oz.	3
Hydraulic Works, High Street,	2 lbs.	3
Hogganfield Loch, near surface,	7 lbs. 8 oz.	5
,, ,, at a greater depth,	8 lbs. 8 oz.	11
Shawlands,	3 lbs. 8 oz.	4

TABLE SHOWING THE DISTRIBUTION OF THE FORAMINIFERA IN THE BOULDER-CLAY OF THE GLASGOW DISTRICT.

Abreviations: r, rare; vr, very rare; c, common; vc, very common.

LIST OF SPECIES.	Hunter's Quarry.	Provanmill.	Hamilton Hill.	Braeside.	Craigpark.	Giffnock.	Helensvale.	Hydraulic Works, High Street.	Hogganfield Loch.	Shawlands.
Miliolina seminulum (Linn.),		vr	f							
,, *subrotunda* (Mont).,									vr	
Haplophragmium Canariense (d'Orb.),			vr							
Textularia globulosa, Ehr.,									vr	
Bulimina pupoides, d'Orb.,			vr	vr						
,, *marginata*, d'Orb.,	r	vr	vr							
Bolivina dilatata, Rss.,			vr							
,, *plicata*, d'Orb.,				vr				vr		
Lagena lævis (Mont.),			vr						vr	
,, *squamosa* (Mont.),									vr	
,, *Orbignyana* (Seg.),	vr					vr				
,, *lucida* (Will.),			vr							
Uvigerina angulosa, Will.,			vr							
Discorbina globularis, d'Orb.,	r									
,, *Parisiensis* (d'Orb).,						vr				
Pulvinulina Patagonica, d'Orb.,										vr
Globigerina bulloides, d'Orb.,	r	vr	r	r	vr	f	r	vr	r	
Orbulina universa, d'Orb.,							vr		vr	
Truncatulina lobatula (W. & J.),			vr		vr	vr				
Rotalia Beccarii (Linn.),		vr	vc	c		vr	vr		vr	
Nonionina depressula (W. & J.),	vr		vc	c		f	r	vr	r	r
Polystomella crispa (Linn.),		vr	r							
,, *striato-punctata* (F. & M.),		r	vc	f		vr				
Cassidulina lævigata, d'Orb.,			vr	vr						
,, *crassa*, d'Orb,			vr			vr				

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No. XXVI.—On the Occurrence of Marine Organisms in the Boulder-clay of the Glasgow District. By James Neilson, *Vice-President*. Part First.

[Read 13th December, 1894.]

The Boulder-clay has always been more or less of a puzzle; and although an enormous amount of research and ingenuity—not to speak of imagination—has been expended on its elucidation, there yet remain as many points in dispute as will probably outlast the present generation of geologists and leave a considerable legacy to its successors.

There are various theories regarding its origin, each defended by its advocates with an amount of heat quite sufficient, had it been evolved at the proper time, to have accounted for any number of mild interglacial periods, if not even for the disappearance of the glacial period itself. The one most generally held is that the Boulder-clay was accumulated as a *moraine profonde*, under a great sheet of land-ice—an enormous mass, 3000 to 4000 feet thick—bearing resemblance rather to the present accumulations of ice over Greenland and the Antarctic Continent than to the glaciers of Switzerland and Norway. Now, while it is no part of my design to draw attention to the objections to this or any other theory, but rather to concentrate interest on the new evidence now to be brought forward in favour of the *marine* origin of the Boulder-clay, I cannot but express a feeling that the *moraine profonde* theory has been arrived at from negative rather than from positive evidence—not so much on account of its own inherent evidence, as from the objections entertained by its promoters to all rival ones.

Another theory is that the great ice-sheet, which covered the country to a depth of from 2000 to 4000 feet, and having distributed through its mass, in the manner pointed out by Professor Forbes, the clay and boulders it had detached from the rocks in its progress, melted away when the milder period came, leaving the Till behind it; and that stratified beds under the Till are due to streams of water flowing under the glacier or ice-sheet.

If the Boulder-clay is the product of land-ice, as held by the supporters of this theory, it could not possibly contain marine fossils; but even if, as some imagine, it was reinforced by ice from

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Scandinavia which may have traversed the German Ocean, that would not account for the fossils in it being in "perfect preservation," and is besides in itself highly improbable, as in such a case it ought to contain boulders from Scandinavian rocks, which the Boulder-clay in our district never does, those found in it being either derived from the immediate neighbourhood or from the north or north-west Highlands.

It must, however, be stated that there are certain Scottish Boulder-clays, as, for instance, that of Caithness and those at one or two localities in South Ayrshire and Wigtownshire, which contain fragments of shells. There is also a shelly-clay in the valley of the Endrick, near the south-east corner of Lochlomond, which was discovered by Mr. Jack, late of the Scottish Geological Survey, and fully described by him to the Society.* But in these cases the shells are not only broken but also rolled and striated, and therefore are as much "boulders" as the striated stones with which they are associated.

All such shelly-clays are believed by Dr. James Geikie† to belong entirely to an upper Boulder-clay, and to be separated from the lower Boulder-clay by a series of interglacial, marine, and lacustrine deposits which were laid down during a period of submergence when the climate assumed a much milder form than had previously existed. These shelly Boulder-clays are all found near the sea margin, and the presence of shells is accounted for by the theory that, with returning cold, the glaciers again covered the sea-bottom, carrying before and under them the shells, rolled stones and other débris which they are now known to contain.

The fact brought to light during the investigations I now bring before your notice, viz., that the Boulder-clay contains the remains of marine animals which evidently lived in or near the spots where they are found, is entirely new to Scottish geology, and will doubtless have great influence on the future geological history of the period. It is quite evident that, should the evidence on this point be considered conclusive, and I have no doubt that it will, these remains were not "boulders" (if it is permissible to call a Foraminifer a boulder) at all, and the land-ice theory of the origin of Boulder-clay must be given up, no matter what its other supposed merits may be.

* *Transactions*, vol. v., page 5.

† "The Great Ice Age." 2nd ed.

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The present communication resulted from a conversation between the author and Mr. Joseph Wright, F.G.S., Belfast, in which the latter stated that he had found many specimens of Foraminifera in the Boulder-clays of the North of Ireland, and that he had a strong impression that these organisms might also be found in the Boulder-clay of the West of Scotland—an impression which he was anxious to verify. Accordingly specimens of Boulder-clay were sent to Mr. Wright from a number of localities in Glasgow and its immediate neighbourhood.

In selecting these samples care was taken in every instance to extract the specimens of the clay from a part sufficiently deep to make sure that it was free from weathering, and, when the underlying rock was visible, sufficiently above it (from 3 to 4 feet), to make certain that the clay did not belong to some bed lying between the Boulder-clay and the rock.

Huntershill, East Quarry, Bishopbriggs.—The specimens from this place were taken during the Society's excursion to Bishopbriggs on 4th May last (1894), and were selected in the presence and with the knowledge of the members present, among whom may be mentioned Mr. Joseph Sommerville, Mr. James Steel, Mr. James White, Mr. William Armour, and others, all of whom considered them to be good typical examples of true Boulder-clay. The Boulder-clay here overlies the sandstone, and is removed to bare the rock for quarrying, being itself utilised for the manufacture of bricks. The clay and upper soil attain a thickness of about 20 feet, and the samples were taken about 3 feet above the rock at a part where the face had been recently cut, so that the clay was quite fresh and unweathered.

A large greenstone boulder, perhaps 5 or 6 tons in weight, lay exposed in the clay a few yards away, and the bottom of the boulder was about the same level as the spot from whence the specimens were taken.

This clay was not so stiff as most of the other Boulder-clays, possibly owing to the nature of the rocks from which it had been derived. The contained boulders were mostly local, and consisted chiefly of white sandstone, carbonaceous shale, and coal, while washing showed the presence of a considerable proportion of light-coloured sand. The boulders were striated in the usual manner, and were generally more or less angular. Scattered here and there

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through it were small beds of laminated clay, as if there had been a period of repose when, free from disturbance, the mud and sand contained in the water had been allowed to settle.

Provanmill.—The specimens taken here were from the deep cutting for the junction of the Caledonian and the Lanarkshire and Dumbartonshire Railways, about 200 yards east of the bridge on the Robroyston Road. This Boulder-clay is of the usual very stiff blue variety so well known in the neighbourhood of Glasgow, and can hardly be distinguished from those at Braeside Street and at Craigpark. The section here showed some very interesting rocks, including coal, fireclay, shale, sandstone, and white trap, and there were several faults or "steps" visible. These rocks were overlaid by Boulder-clay from 12 to 20 feet thick. Unfortunately most of the section has since been built up during the completion of the railway works.

Hamilton Hill.—This locality is well known to members of the Society, as evening walks to it have sometimes formed part of the excursion programme. I presume this is the place mentioned by Dr. James Geikie, when he says,* "My friend Mr. Jack informs me that at Port Dundas bricks are made out of a typical stoney Till, the stones being crunched up by a machine." Although the locality is rather far west to pass for Port Dundas, still the description is otherwise quite applicable. Boulder-clay is still cut from the eastern end of Hamilton Hill for brick-making, but the part from which the specimens for the present inquiry were selected was the deep cutting worked by the Canal Company, the clay being shipped for the upkeep of the canal banks. It is stiffer than that from Huntershill, and the proportion of clay to stones is greater than in any of the other localities mentioned in this paper.

This is the deepest cutting I know of in Boulder-clay. According to a workman's statement the section is about 110 feet deep, and there are about other 10 feet of clay down to the level of the canal. The rock is not anywhere seen, so that unfortunately we can get no indication of the total thickness of the deposit; but as the highest point of the hill has not yet been reached, the thickness will naturally increase as the quarry is worked backwards. As showing the tough nature of the clay, we were told that it is regularly blasted.

* "Great Ice Age," p. 8.

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The boulders which have been taken out of the clay lie about in great heaps, and there is no better way of becoming acquainted, not only with the rocks of the West of Scotland, but also with the manner in which such rocks have been acted on by ice, than is afforded by a visit to Hamilton Hill. The specimens of clay were taken from this place about 3 feet above the floor of the quarry; but this may not indicate their true position in the section, as the face is constantly slipping down during the working.

Braeside Street.—Operations have been carried on in this neighbourhood for a number of years, with the view of sweeping away a hill on the south side of Garscube Road, near its junction with Gairbraid Street. The clay, when cleared of stones, was made into bricks, and no sooner was the ground levelled than buildings were erected upon it. Although not far distant from Hamilton Hill, yet the clay at Braeside Street differs considerably from the deposit there, being stiffer, bluer in colour, and containing more boulders. The specimens were selected from a point in a line with the centre of Braeside Street, and about 50 yards south of Garscube Road. They were perfectly fresh, being dug by the author from a face at which the men were working, at a depth of about 15 feet below the surface.

Craigpark Street, Dennistoun.—The specimens at this place were taken from a pipe- or drain-cutting, opposite Regent Place U.P. Church, in which the clay bore a very strong resemblance to that last described.

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No. XXVII.—On the Occurrence of Marine Organisms in the Boulder-clay of the Glasgow District. By James Neilson, *V.P.* Part Second.

[Read 30th May, 1895.]

In laying before the Society a Second Report, I may state that specimens from several of the former localities have been again gone over, and that samples from the following new ones have also been examined.

Helenvale Street, Parkhead.—The Boulder-clay was exposed here in the foundation for a bridge in the railway cutting. The first sample was taken during the intense frost of this winter. It showed only one specimen in 5 lbs. of material. As there was some doubt as to whether the frost might not have destroyed some of the organisms, a fresh sample was taken after the frost had disappeared, and it showed more favourable results.

Giffnock.—The specimens here were taken from the top of the opencast sandstone quarry to the east of the quarry tunnels. The first specimen obtained was frosted and showed very poor results, but the second sample proved much more satisfactory.

Hoganfield Loch.—Two samples were taken at this place during the sinking of a pit situated to the east of the loch. One sample was got from near the surface, and the other at a greater depth.

Robroyston.—The specimen here was taken from the top of the sandstone quarry near the roadside, fully half a mile north of the railway bridge at Provanmill.

Shawlands.—This sample was got from a drain-cutting in the road near Pollokshaws (East) railway station.

Corporation Hydraulic Works, High Street.—The specimen of the clay here was taken from a pipe-cutting at these works.

Hamilton Hill and Braeside Street.—Additional specimens of clay were also got from these localities.

For the specimens from the first four localities I am indebted to my friend Mr. J. B. Wise, who also discovered the Robroyston locality, and accompanied me when I secured the specimen. For the High Street specimen I am indebted to my friend Mr. Purdie.

The whole of the samples taken were thickly charged with glaciated stones, and there can be no doubt whatever that all of them represented true Boulder-clay.

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Huntershill was the only locality in which any trace of stratified beds in the Boulder-clay was discovered, and Hamilton Hill contained a smaller proportion of stones than any of the others. In other respects the whole of the beds were very much alike, and they were all composed of the typical clay so well known in the neighbourhood of Glasgow.

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No. XXVIII.—On the Old Red Sandstone and Carboniferous Rocks of the North End of the Island of Arran. By James Neilson, *Vice-President.*

[Read 17th October, 1895.]

If there is one canon in geology more firmly established than another, it is that fossils indicate a certain definite time in the earth's history, that the various species which they represent appeared, lived, and died out at certain definite times, and that, therefore, fossil evidence has come to be considered the most trustworthy of all evidence as an index to the age and succession of the various rock-formations. In fact, that, as Dr. Mantell put it, fossils are the "Medals of Creation." Associated with this there is another belief, viz., that the various formations succeeded each other in a certain distinct order, *one at a time;* that each formation was newer than that below, and older than that overlying it, but was contemporaneous with neither.

With these beliefs, it appears, however, that Sir Archibald Geikie does not agree, at least, judging from the third edition of his "Text Book of Geology," 1893, according to which fossils cannot be depended on as indications of the age of rocks, as they may be found in formations to which they do not really belong; and that the difference between two formations may be geographical rather than geological, as two entirely separate formations may have been formed contemporaneously in different, though possibly neighbouring, geographical areas.

Thus, at page 665, it is stated that in Bohemia and Russia some of the most characteristic Upper Silurian organisms are found beneath strata full of Lower Silurian life forms. At page 760, when speaking of the close of the Silurian period, it is said —"There is every reason to believe that for a long time the marine sedimentation of Upper Silurian type continued to prevail in some areas, while *the probably lacustrine* type of the Old Red Sandstone had already been established in others." At page 828 we find—"In the West of Scotland there occur among the red sandstones (some of which contain Old Red Sandstone fishes) bands of limestone full of true 'Carboniferous limestone corals and brachiopods.'" At page 665 we read—"In Australia a flora with Jurassic affinities and a Carboniferous limestone fauna were

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contemporaneous," and again at page 660—"At the present day, the higher fauna of Australia is more nearly akin to that which flourished in Europe far back in mesozoic time than to the living fauna of any other region of the globe."

Without passing any opinion as to the general bearing of these extracts, I propose to consider them so far as regards the question whether marine Carboniferous limestone fossils are, or are not, found in Old Red Sandstone strata in the West of Scotland, and this is the more important as it is, I understand, the only example Sir Archibald gives of the interlapping of Old Red Sandstone and Carboniferous strata. Consequently, if this instance fails, his whole theory, so far as these formations are concerned, must be modified.

It will here be necessary to make a lengthy quotation from the chapter on "Old Red Sandstone" (page 801)—

"In the Upper Old Red Sandstone of the Firth of Clyde, *Bothriolepis (Pterichthys) major* and *Holoptychius* occur at the Heads of Ayr, while a band of marine limestone lying in the red sandstone series in Arran is crowded with ordinary Carboniferous limestone shells, such as *Productus giganteus*, *P. semireticulatus*, *P. punctatus*, *Chonetes hardrensis*, *Spirifer lineatus*, &c. These fossils are absent from the great series of red sandstones overlying the limestone, and do not reappear till we reach the limestones in the Lower Carboniferous series; yet the organisms must have been living during all that long interval outside of the Upper Old Red Sandstone area.

"Not only so, but they must have been in existence long before the formation of the thick Arran limestone, though it was only during the comparatively brief interval represented by that limestone that geographical changes permitted them to enter the Old Red Sandstone basin, and settle a while on its floor.

"The higher parts of the Upper Old Red Sandstone seem thus to have been contemporaneous with a Carboniferous limestone fauna, which, having appeared beyond the British area, was ready to spread over it as soon as the conditions became favourable for the invasion. It is, of course, obvious that such an abundant and varied fauna as that of the Carboniferous limestone cannot have come suddenly into existence at the period marked by the base of the limestone. It must have had a long previous existence outside the present area of the deposit."

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This subject is also returned to (page 828) when the author is treating of the Carboniferous system, thus—

"In the West of Scotland there occur among the red sandstones (some of which contain Upper Old Red Sandstone fishes) bands of limestone full of true Carboniferous limestone corals and brachiopods. Hence, it is evident that the Carboniferous limestone fauna had already appeared outside the British area before the final cessation of the peculiar conditions of sedimentation of the Old Red Sandstone period."*

I confess to a little difficulty in grasping the exact meaning of the above-quoted passages, but the natural reading seems to be that the red rocks of Arran contain Old Red Sandstone fishes, and, from similar statements made in certain modern text-books,† it is plain that their authors understood them in the same sense. As for example—"Too much weight must not be attached to the character of the fossils in the limestone for the purposes of stratigraphical classification, since, as is well known, there occur in the West of Scotland, among red sandstones yielding Old Red Sandstone fishes, bands of limestone full of corals and shells of common Carboniferous limestone species. See Geikie, *op. jam cit.* [*i.e.*, second edition of the "Text-Book"], pages 716, 739."‡

The fact is that no Old Red Sandstone fishes have ever been recorded from, and, so far as I am aware, none have ever been found in Arran, nor are there in the West of Scotland any red sandstones yielding Old Red Sandstone fishes together with bands of limestone full of corals and shells of common Carboniferous limestone species. The fishes referred to in the "Text Book" were, I presume, the specimens discovered in red sandstone south of the Heads of Ayr, on the mainland, some 20 miles distant from the Arran limestones. But the fact that Old Red Sandstone fishes have been got near the Heads of Ayr (where there are no Carboniferous limestone fossils) by no means proves that Arran limestones charged with Carboniferous limestone fossils (where there are no

* See also "Text Book," 2nd ed., 1882, p. 716, 739.

† See "Geology: Chemical, Physical, and Stratigraphical," vol. ii., p. 93, by Joseph Prestwich, M.A., F.R.S., F.G.S., 1888; and "Historical Geology," by A. J. Jukes Browne, B.A., F.G.S., 1886, p. 139.

‡ "Handbook of the Geology of Northumberland and Durham," edited by Prof. G. A. Lebour, M.A., F.G.S., p. 77. This book formed the Official and Local Guide issued for the visit of the British Association to Newcastle-upon-Tyne, 1889.

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Old Red Sandstone fishes) belong to the Old Red Sandstone formation. And it is noticeable that while no remains of plants have been recorded from the red sandstones of the Heads of Ayr, those of Arran both above and below the limestone are charged with fragments of Carboniferous plants.

Arran is classic ground to the geologist; its fame has travelled far beyond the limits of the United Kingdom, and the problems it presents have engaged many able pens. Amongst others, Sedgwick and Murchison,* Ramsay,† and Bryce,‡ have written of these particular rocks, and all of them identified not only Old Red Sandstone but also Carboniferous strata.

The northern half of the Island of Arran consists—1st, of a central granite nucleus of somewhat circular form, which contains all the higher hills. The granite nowhere reaches the sea, being surrounded by a complete ring of slate and schistose rocks. These again are overlaid by another series (of which red is the prevailing colour), but these rocks do not completely surround the last-mentioned ones, as they do not appear on the north-west side. Previous writers assigned these latter rocks partly to the Old Red Sandstone and partly to the Carboniferous formations, and it is to them that I now propose to direct your attention, going over the evidence already recorded, arranging it in form for discussion, and adding some further observations of my own.

Investigation of the Arran rocks is much facilitated by the fact that the upheaval of the granite (or the final upheaval, if there was more than one) occurred subsequent to the deposition of the highest of the sedimentary rocks, which are upheaved all round the coast, and their upturned edges, which are exposed all along the Raised Beach down to low-water mark, afford unrivalled opportunities for observation.

As was first pointed out by Sedgwick and Murchison, the lowest of these Old Red Sandstone strata are seen at North Sannox, where there is an anticline from which the rocks dip north and south. They consist mostly of red sandstones and conglomerates, and, as will readily be acknowledged, those north of the anticline

* *Proceedings of the Geological Society of London*, vol. i., p. 41, 1828. This appears to be only an abstract of their paper.

† "Geology of the Island of Arran," by Sir Andrew Crombie Ramsay, 1841.

‡ "Geology of Arran and the other Clyde Islands," by James Bryce, M.A., LL.D., &c., 4th edition, 1872.

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correspond with those to the south. These writers set them down as Old Red Sandstone, which formation, according to them, extends for about 3 miles along the shore—the northern junction with the Carboniferous rocks occurring north of the Fallen Rocks, and the southern junction ¼ of a mile north of Corrie, *i.e.*, 100 yards north of the great split boulder which forms such a conspicuous object on the shore. They are overlaid by Carboniferous rocks for several miles both north and south of these points, and are finally overlaid by strata of New Red Sandstone age.

Ramsay also supports this theory, and Bryce differs from it only in referring the uppermost rocks to the Upper Carboniferous instead of to the New Red Sandstone formation.

No time need be lost in discussing the beds which Sedgwick and Murchison state are Old Red Sandstone, as the fact is admitted on all hands. The question to be decided is whether the beds considered by these, and subsequent writers, to be Carboniferous are really so, or whether they are Old Red Sandstone, as stated in the "Text Book."

Coming for this purpose to the junctions of these two formations we find that both on the north and south the Old Red Sandstone conglomerates are succeeded by calcareous conglomerates and concretionary limestones (cornstones) alternating with sandstones. These strata overlie the Old Red Sandstone conglomerates conformably, and if Arran alone had been in question it is doubtful whether the line would have been drawn here. Some geologists hold that at least part of that which is considered to be the Upper Old Red Sandstone should be tacked on to the Carboniferous system. We have not observed in Arran anything condemnatory of that opinion. At least, in the absence of Old Red Sandstone fossils, the differences in the strata are no greater than those between different divisions of the Carboniferous formation.

Unfortunately the strata at the south end are cut off about 50 yards from this junction by a dyke, of which the cross section extends for more than 320 yards along the shore. As it seems to me that this dyke marks a fault, cutting off a considerable thickness of strata, I am compelled to fill in the gap by referring to the corresponding northern section, where we find that the same cornstone series is overlaid by beds of sandstone, black shale, and volcanic ash. This shale contains charred plant-remains belonging

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to the genera *Calamites*, *Lepidodendron*, and *Lepidostrobus;* also a species of *Spirorbis;* besides, and of more interest, the remains of fishes. Dr. R. H. Traquair reported upon the latter as follows:—

"The fish remains from Arran, submitted to me by Mr. Neilson, are unfortunately so fragmentary that it is scarcely possible to identify any of them specifically. All that I can do is to indicate the general affinities of some—while, as regards others, I can say nothing.

"No. 1 is a portion of the basal end of a rhizodont tooth, which I should have attributed to *Rhizodus* itself had there been any trace of the lateral trenchant edges characteristic of that genus. As, however, the distance from the base of the tooth where these edges begin to be prominent in ordinary specimens of *Rhizodus*—teeth vary in different individuals—I hardly like to say that it does *not* belong to that genus. It wants the fine striæ seen in *Strepsodus Portlocki*, which it resembles in the oval form of its transverse section.

"No. 2 is a small rhizodont tooth which it is also very difficult to refer with certainty to its genus or species. In shape and appearance it most resembles the smooth variety of *Strepsodus striatulus*, Traq., from the Carboniferous limestone series of the East of Scotland.

"No. 3 is an imperfect scale also belonging to the rhizodont family.

"Nos. 4 and 5 are small palæoniscoid scales which, judging from the comparatively coarse serration of their posterior margins, probably belong to the genus *Rhadinichthys*, Traq., but more it is impossible to say.

"Although the specimens are unfortunately not such as to permit me to give any list of species, it is to be noted that they exhibit an unmistakably Carboniferous facies."

It should be noted that these fossils were obtained from a very small part of the shale and that, were it properly opened out, a largely extended list might be the result.

Overlying this bed is one of volcanic ash, also containing fish remains—consisting, so far as my examination went, of fragments of bones and scales, some pretty large, but I was not fortunate enough to find any of them in a condition to admit of identification.

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My informant as to the ash-bed was our old honorary member Mr. James Thomson, F.G.S.—whom I believe to be its discoverer —and, when hunting for it, I came across the black shale-bed above mentioned.

It speaks volumes for the accuracy of the earlier writers upon Arran that here, within a few yards of the line they drew as separating the Old Red and the Carboniferous formations, a bed charged with characteristic Carboniferous fossils should be found. So far as I am aware this is the lowest horizon where Carboniferous species have been got, occupying as it does a position several hundreds of fathoms below the marine limestones which, according to the "Text Book," are in the Old Red Sandstone formation.

When proceeding onwards it should be remembered that owing to the anticline the rocks dip away from us in the direction in which we are travelling, so that we see first only their upturned edges. It will thus be evident that each bed we come to is higher in the section than the preceding one, and that, as the strata dip at angles of from 20° to 70°, a mile along the shore represents a considerable thickness of strata. For a distance of about 3 miles from this point onward the red colour of the rocks is very occasional indeed, and not till we pass the Salt Pans does the red rock again predominate, and then (as will afterwards be shown) at a horizon several thousands of feet higher in the geological scale.

Succeeding and overlying the fish-beds we have next a great thickness of white and grey calciferous sandstones, and, passing them, at Millstone Point, about 1 mile north of the Fallen Rocks, we come on black shales full of plant-remains in the condition of anthracite.

Shortly after this we reach the interesting sections of trap and ash-beds, interbedded with shales and thin seams of coal, amongst which Mr. Edward A. Wünsch, F.G.S.,* long an active member and vice-president of our Society, made his interesting discovery of a forest buried in volcanic ash, yet buried in such a way as to preserve the minute structures of the plants. Mr. Wünsch recorded† the disinterment of fourteen large tree-stems, and

* I regret to state that since this paper was read Mr. Wünsch has died. His death took place in Cornwall on the 19th November, 1895. A short obituary notice was given in the *Geological Magazine* for February, 1896.

† *Transactions*, vol. ii., p. 97. For descriptions of new species from this deposit, see the monographs of the Palæontographical Society, 1870.

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some others were taken out during the meeting of the British Association in Glasgow in 1876. Dr. Bryce also recorded (page 127) the finding of a palatal tooth of *Ctenodus cristatus* (surely a Carboniferous fish). The plants recorded from this bed are *Sigillaria*, *Halonia*, *Lepidodendron*, *Lepidostrobus* (three sp.), *Antholithes*, *Sphenopteris*, and *Stigmaria*.

Mr. Wünsch estimated the thickness of these igneous rocks with the interbedded shales, &c., at about 1000 feet, and probably between them and the Old Red Sandstone conglomerate there is at least as much more, even with a liberal allowance for faulting. We are now near the limestone, which we reach after passing some white or grey sandstone, so that there are here some 2000 feet of strata not red, underlying the fossiliferous limestones. I do not hesitate to assign these strata to the calciferous sandstone series, and the great thickness of igneous rocks, in which Mr. Wünsch's discovery was made, to the huge outburst of trap which marks the close of the calciferous and the beginning of the lower limestone periods, and, extending across Scotland, gives us the trap hills of South Bute, Little Cumbrae, North Ayrshire, Kilpatrick, Campsie, Fifeshire, and the Lothians.

Should this be the case, it may be more than a coincidence that in the three principal localities where fossil wood showing minute structure has been found, viz., in the present beds, at Burntisland, and at Bowling, the same series of volcanic rocks should have enveloped the forests in such a way as to preserve the microscopic structure of the trees. It is just within the limits of possibility that this may mark a distinct horizon.

The fossiliferous limestone which occurs about 100 yards north-west of the shepherd's house at Laggan is undoubtedly the same as that at Corrie, and contains the same fossils, the prevailing one being *Productus giganteus*, which is extraordinarily abundant. The peculiarity about the Laggan beds is that the shales are black, while at Corrie they are red, which shows that the red colour does not help us to identify strata, as it does not represent a difference of thousands or millions of years, but is merely a local phenomenon. These limestones are succeeded by white and grey sandstones, with alternating black shales. Some of the shales are charged with the usual marine Carboniferous fossils, and extend along the shore to Salt Pans, where they are succeeded

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by beds of a different character, but as these beds are not represented on the southern part of the district it is better to defer their consideration till I have finished with the others.

Let us now return to the consideration of the similar beds at the southern portion of the section, where we left off, viz., at the broad dyke of which the southern edge terminates on the shore opposite the school-grounds at Corrie. As already stated, this dyke marks a great fault, and I am rather surprised that the present should be the first mention of it, as the evidence seems clear enough. The cornstones occur immediately to the north of it, while the marine limestones are only a few hundred yards south; so that it cuts off all the strata represented along about 2 miles of shore on the northern section (*viz.*, from the cornstones north of the Fallen Rocks, to the shepherd's house at Laggan), *i.e.*, nearly all the calciferous sandstone series, a displacement which may be roughly estimated at about 300 fathoms. I am under the impression that, failing to recognise the existence here of a great fault, Sir Archibald Geikie wrongly supposed the marine limestones to be in their natural position only a little way above the cornstones.

To the south of this dyke the strata are mostly, though not all, of a red colour, and consist of sandstones, shales, limestones, ironstones, and (what have not previously been noted) various beds of fireclay. The beds known as the Corrie limestone consist, we are told, of twenty-two beds of limestone interstratified with red shale, the total thickness of the limestone being about 20 feet. These are referred to in the "Text Book" *thus—"A band of marine limestone lying in the red sandstone series in Arran is crowded with ordinary Carboniferous limestone shells, such as *Productus giganteus, P. semireticulatus, P. punctatus, Chonetes hardrensis, Spirifer lineatus*, &c." This part of the quotation I very heartily endorse, the strata, consisting of sandstones, shales, &c., being mostly red. Even the limestone fossils are as red as the sandstones, and they occur in great profusion. *Productus giganteus* exists by the million, and one of the sights, even of Arran, not only for the geologist, but also for the ordinary summer visitor, is to stand at the entrance of one of the old mines, and see this shell not only crowding the roofs, but many layers of

* "Text-book," p. 801.

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the rock, the concave dorsal valves of one generation serving as the resting-places of the next succeeding one.

Owing to a great upthrow, these limestones appear on the northern flank of the hill called Maoldon, where they have been worked for industrial purposes. They are similar in character and colour to those of Corrie, but the fossils are more easily procured. Several magnificent slabs crowded with shells, and fit for any museum, are to be seen lying among the fallen débris, and when among them I could not resist the temptation of chiselling the shale out of some of the shells, so as better to expose them, a work which, it is to be hoped, will be appreciated by some future geologist. Three other upthrows of the same limestones occur further to the south, on the slopes towards Brodick Bay, but it is unnecessary to refer to them at the present time. There can be no doubt that these are the same limestones as those previously observed on the north shore, near the shepherd's house at Laggan. Generally speaking, the fossils are the same, as is also the character of the limestone and the interbedded shale, in all but the colour.

With regard to the redness of the strata, on which the "Text Book" lays some stress, it is simply due to hematitic iron ore distributed through the rock, and many seams have this to such an extent as to soil the hands, while some of the fossils do so even even after years of exposure to the weather. These ores also appear sometimes as seams of red ironstone, and at other times are aggregated into detached nodules or nodular bands, good examples of both kinds being met with in old quarries on the hills behind Corrie, and also on the shore. But, although red is the prevailing colour, it is not by any means universal, as white sandstones are, and have been, quarried behind the village, both above and below the limestones, *e.g.*, in a quarry behind Corrie Hotel, where a white sandstone may be seen overlaid by a bed of fireclay containing the usual rootlets of *Stigmaria*. As has already been shown, the same limestones, shales, and sandstones which are red at Corrie are respectively black and white at Laggan, so that I believe the redness to be only a local peculiarity in the same strata.

Taking up the last quotation at the point we left off, we find*—

* "Text-book," p. 801.

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"These fossils [*i.e., the limestone fossils*] are absent from the great series of red sandstones overlying the limestones, and do not reappear till we reach the limestones in the lower Carboniferous series; yet the organisms must have been living during all that long interval outside of the upper Old Red Sandstone area" (page 828). I admit that the limestone fossils are absent from the great series of red sandstones, but I challenge the production of even a single fish of the Old Red Sandstone formation from any part of the Island. That marine fossils should be "absent from the great series of red sandstones overlying the limestone" was to be expected, the fossils found in Carboniferous sandstones elsewhere being exclusively plant-remains, and I am only aware of one bed of sandstone which contains marine remains, in the West of Scotland, and that one is in the upper limestone series.

Plant-remains are even more common in Arran than I have observed them elsewhere, a fact, already sufficiently recorded by previous writers, which may be easily verified by anyone who walks along the shore at Corrie, where they protrude every here and there from the sandstones, while one sandstone bed, intercalated between the limestones in front of Corrie Hotel, is packed with rootlets of plants. Plant-remains are also abundant all along the northern sections, and also towards the south in the cliffs of Maoldon.

A notice of a section at Lochrim Burn, ¼ of a mile south of Corrie, where there is exposed a bed of red sandy shale with marine fossils, will be found in the *Transactions* of the Edinburgh Geological Society,* the list containing fifteen species, certified by Mr. John Young, LL.D., F.G.S., every one being common in the Carboniferous limestone strata of the West of Scotland. This bed is overlaid by another containing abundant plant-remains, of which a list of seven species is given. The Rev. David Landsborough of Kilmarnock found here another plant, viz., *Carpolithes sulcata*, L. & H.,† which Mr. Kidston considers to be characteristic of the calciferous sandstone series. I considered the point of importance in determining the position of a great fault which passes at some place close at hand, and which throws up the Corrie limestone at Maoldon. If these strata are calciferous, then

* *Trans. Edin. Geol. Soc.*, vol. v., p. 316.

† Lindley and Hutton's "Fossil Flora," plate 220.

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the fault is to the north; while if they belong to the limestone series, it probably passes to the south. It seems to me, however, that the evidence is rather in favour of them belonging to the limestone series.

Although the plant-remains of Arran are in a very poor state of preservation, yet I have been able to identify the following genera:—

Calamites, - - -	Maoldon—(changed into ironstone).
,,	Ash, shale, north of Fallen Rocks.
,,	Millstone Point.
,,	Corrie.
Lepidodendron, - -	Maoldon—at cliffs, in lime-working.
Lepidostrobus.	
Sigillaria (large stems).	
Stigmaria ficoides, -	Everywhere.

Besides these there are innumerable rootlets and unrecognisable fragments scattered through the red, yellow, and black shales.

Then, as already noted, there are the fireclays, of which there are several distinct beds along the Corrie shore. There is also a bed of fireclay in the old quarry behind Corrie Hotel (within 100 feet of the *Productus giganteus* limestone). This overlies a bed of fine, white sandstone. Fireclays also occur at Lochrim Burn, south of Corrie, while several crop out on the northern cliff of Maoldon, and also in the gap between the northern and the great north-eastern cliff.

So far as I know, fireclays have not hitherto been recorded from Arran, but they have an important bearing on the question presently at issue. Let me here again quote the "Text Book"* —"Fireclay or shale, through which rootlets branch freely in all directions. . . . They appear to be the soil on which the plants of the coal grew." These Arran fireclays differ in no respect, except that some of them are redder or whiter, from those we are so familiar with in the vicinity of Glasgow, being crowded with rootlets, while here and there the familiar *Stigmaria ficoides* is to be seen. Some of them show the peculiar slickensides so well known, and nodules of ironstone are distributed through them. I am under the impression that fireclays are not known to occur earlier than in the Carboniferous formation. At all events, the "Text-book" does not mention them as occurring in the Old Red Sandstone.

But not only do these red sandstones contain fireclays, but also ironstone, which occurs not only as nodules (in the fireclays and

* "Text Book," p. 806; see also p. 514.

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shales) from half the size of pin-heads to about a foot in diameter, also in nodular and regular bands, which may be seen at Corrie, both on the shore and in the old quarries already referred to, and on Maoldon and in the Mill burn at Brodick. The ironstone is nearly all in the state of peroxide—hematite iron ore, which is doubtless the colouring material of all the red rocks of Arran; in fact, I have come to the conclusion that the nodules, and possibly seams of hematite, have been simply segregated from the abundance of this material—one very striking instance of a nodular band, about an inch thick, seeming to have entirely exhausted the red matter from the clay in which it lies, leaving it of a creamy white colour.

Let us return now to the question of the marine limestones. If they belonged to the Old Red Sandstone age, we should expect their fossils to be of Devonian rather than of Carboniferous type. It would indeed be strange if there should have existed at the same time in the sea, where Devonshire and Arran now are, two faunas so dissimilar as those of the Devonian and Carboniferous, if changes should have occurred which involved the annihilation of the entire Old Red Sandstone and Devonian faunas, and yet have left these Carboniferous fossils unchanged throughout all the long period represented by the upper members of the Old Red Sandstone, and the whole of the calciferous sandstone period, to be again introduced unaltered into the British area at the beginning of the Carboniferous limestone period. On the contrary, the proof is all the other way; the fossils show undoubtedly that these are true Carboniferous limestone strata. Bryce* records from them some thirty-six species of marine fossils, all found elsewhere in the Carboniferous series of the West of Scotland. Nay, as if to render the Old Red Sandstone theory more manifestly untenable, four of these species are fishes of Carboniferous type, of which two are got at Corrie, viz., *Megaclichthys Hibberti* and *Cochliodus magnus*.

The most striking feature in the limestones at Corrie and at Laggan and Maoldon is the enormous number of the shells of *Productus giganteus*.† Now, it will be generally conceded that

* "Geology of Arran," p. 224.

† Measuring a square yard in the roof of one of the mines I counted in it 48 shells of this species, and in the face section I counted 21 layers of the shells. A simple calculation shows that at this rate an imperial acre contained over 232,000 shells per layer, and 21 layers would yield nearly 5,000,000 shells per acre—a number which, however enormous, is, I am persuaded, under rather than over the actual amount.

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species, like individuals, have first a period of infancy, and then of full development, after which they dwindle and gradually die out. This shell has been no exception to this rule, and its period of overwhelming development is well known in the West of Scotland, near the bottom of the limestone series, where some of the beds are known as the *Productus giganteus* limestone. This series of beds, the thickest of our lowest limestones, generally called the main limestone, has been extensively worked at Beith and Dalry, near Busby, at Hurlet, Campsie, and Carluke, amongst other places, and there need be no hesitation in setting down the Corrie limestones as its equivalents in Arran. In position they correspond stratigraphically, if we accept Mr. Wünsch's ash-beds as part of the great igneous outburst of calciferous sandstone age.

Part II.

I intended to have re-examined the rocks in Brodick Bay, so as to have worked out the evidence in that direction, but the broken weather of last summer stopped that portion of my work. I may, however, say that the evidence there is not so complete nor so continuous as in the ground I had already gone over, while the greater part, if not the whole, of the strata between those already described and the thick sandstones which overlie the upper limestone near the Cock of Arran, appear to be entirely awanting.

I shall therefore take up the strata on the north coast of the island at the point where we left off, half a mile north of the shepherd's house at Laggan. This part is generally called Salt Pans, but I have hitherto avoided the name, desiring to reserve it for the higher strata about to be described. These consist of sandstones and shales with two or three seams of coal which have been wrought down to the level of the sea, also several bands of ironstone. In one little bay there are exposed three beds of hematite ironstone, beautifully tessellated, and forming a very interesting and striking object well worthy of a visit.

No marine remains have been recorded from these strata, but they contain numerous plant-remains, mostly unrecognisable, although *Stigmaria* is common. I found, however, one small frond of *Sphenopteris*. These beds have evidently been deposited in fresh water.*

* Dr. Bryce ("Arran," p. 128) states that "the shale and coal tract is bounded by a black limestone below, and red limestone above, 1400 yards apart."

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These strata lie between the upper and lower limestone series and are, I believe, the representatives of what is known in the West of Scotland as "the middle coal and ironstone group," represented near Glasgow by the Possil and Govan coals and ironstones, with which they correspond in geological position, mineral character, and economic products (coal and ironstone), although I have not observed in the Arran beds the *Lingula* which elsewhere is so characteristic of this division.

Part III.

Proceeding still in a north-westerly direction along the shore we reach another series of red rocks—even redder than before—which consist of sandstones, shales, and several limestones. The limestones are loaded with fossils, one bed, the lowest, being charged with the shells of *Productus latissimus*, while another abounds with large stems of *Encrinites*, and a third with various other fossils. These exhibit a decided change from the last group of beds, viz., from fresh-water to marine conditions. Not only the beds themselves, but the fossils they contain are as red as any Old Red Sandstone rocks in Scotland. I set them down as the equivalents of the upper limestone series, to which they correspond in stratigraphical position, and am inclined to consider the bed, charged with *Productus latissimus*, as the true "Index" limestone itself. This shell attains its greatest development at a certain horizon known as the *Productus latissimus* limestone.

Overlying these rocks we come to thick beds of sandstone, then breccias, then sandstones again, till the whole are cut off by a great fault, the slates coming down to the shore. These sandstones, &c., were described by Sedgwick and Murchison, and by Ramsay, as belonging to the New Red Sandstone formation, while Bryce sets them down as belonging to the Upper Carboniferous series (I presume the equivalents of the Bothwell red sandstones which overlie the highest of the Lanarkshire coal-seams).

It will, however, be observed, if my theory is correct, that these sandstones occupy the position of the millstone grit, and, as there does not appear to be any break or unconformity in the sequence, I am inclined to relegate them to that position.

In the New Geological Map of Scotland, 1892, these rocks are

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set down as Upper Old Red Sandstone, but they clearly overlie thousands of feet of strata containing Carboniferous fossils, while the pebbles in the associated breccias contain fossils of Carboniferous limestone age, originally discovered by Mr. James Thomson, F.G.S., a fact well known to the members of this Society twelve years or so before the publication of the map referred to. But I can see no necessity for placing these rocks either on the horizon of the Bothwell sandstone, or of those of Ballochmyle or Dumfries.

Lying conformably as they do over the upper limestone series they occupy the position of the millstone grit, and *prima facie* they are these beds, the onus of proof being therefore thrown on those who would dispute this point. The omission of the Upper Coal measures would likely be marked by some unconformability, while none is recorded; and that the phenomena of their stratification are not sufficient to locate them satisfactorily is amply shown by the fact that they have been set down by three distinguished geologists as belonging respectively to the New Red Sandstone, to the Upper Carboniferous, and to the Upper Old Red Sandstone periods. Considering these rocks then as of millstone grit age, and the highest in the North of Arran, it is evident that the Upper Coal measures are absent.*

The synopsis of the Carboniferous limestone series given in the New Geological Map of Scotland, 1892, is as follows† :—

CARBONIFEROUS LIMESTONE SERIES.

Group of sandstones and shales with three or more seams of limestones (Castlecary, Calmy or Arden, and "Index" limestones).
Sandstones, shale, coals, and ironstones, but with no limestone bands.
Sandstones, shales, fireclays, coals, and ironstones, with several thin limestones (Hosie's) towards the top, and the thick Main or Hurlet limestone at the bottom.

This, as will be seen, agrees with the character of the Arran rocks.

Having now given a survey of the whole, I claim that, both

* Ramsay ("Arran," p. 33) says—"These rocks rest conformably above the Carboniferous formation." Bryce says nothing about it. The statement in the Report of the Science and Art Department, 1894, p. 284 (see extract at p. 300), that "the Red Sandstone conglomerates and breccias lie unconformably on the Carboniferous formation" is, so far as I am aware, a new discovery, and disposes of my objections to consider these rocks as New Red Sandstone. The rocks below this unconformity I still hold to be of millstone grit age.

† Explanatory Notes accompanying "A New Geological Map of Scotland," 1892.

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on account of stratigraphical, mineral, and fossil evidence, these Arran rocks are the equivalents of the West of Scotland Old Red Sandstone and Carboniferous strata, and I venture to correlate them as follows:—

	Mainland.	Arran.
[Upper Coal Measures,	Lanarkshire,	Absent.]
Millstone Grit,	Bishopbriggs,	Cock of Arran.
Upper Limestone Series,	Highfield,	Salt Pans.
,,	Arden,	,,
,,	Orchard,	,,
,,	Cowglen,	,,
Middle Ironstone and Coals,	Possil, Govan, &c.,	,,
Lower Limestone Series,	Campsie,	Laggan.
,,	Hurlet,	Corrie.
,,	Carluke,	Maoldon.
,,	Beith,	Brodick.
Great Volcanic Outburst,	Ayrshire Hills,	Mr. Wünsch's discovery.
,,	Campsie,	
Calciferous Sandstones,	Ballagan,	Lagantuin Bay.
,,	West Calder,	,,
,,	Edinburgh,	,,
Old Red Sandstone,		¼-mile north of Corrie to Fallen Rocks.

It has been already mentioned that the ring of slates or schists completely encircles the granite, yet the New Geological Map of Scotland, 1892, shows on the east the granite in contact with the Old Red Sandstone for a distance of about 3 miles. That this is not the case can be seen in the White Water, described in the books of the authors already quoted, and also in the Punch Bowl, or Cioch na h-Oighe junction, discovered and first described by our esteemed member Mr. John Smith,* where the granite and slate are clearly in contact. On the eastern slope we have in the Map the Lower Old Red Sandstone, then Upper Old Red Sandstone, succeeded by calciferous sandstone, and that again by Upper Old Red Sandstone; but I hold that there are no Lower Old Red Sandstone rocks in this part of Arran. We are told* that the Lower Old Red Sandstone is "covered unconformably by every rock younger than itself," but all the red rocks I have seen lie conformably to one another. The beds near the Cock of Arran, set down as Upper Old Red Sandstone, overlie something like 1000 fathoms of strata which are charged with Carboniferous fossils, and contain marine limestones, workable seams of coal, fireclays, and ironstones.

* "Text-book," p. 799.

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Part IV.

Some very striking instances of what appear to be the results of segregation are met with in this district. In one place we have red limestone (cornstone) with white nodules, as if by some subtle force the iron which at one time coloured the whole bed had been driven out from the portions which are now nodules. This is succeeded by another bed in which exactly the opposite is the case, the iron being drawn completely out of the general body of the stone and concentrated in the nodules, which are red in a white matrix.

The colouring matter of the red rocks is peroxide of iron, of which a very small quantity will colour a large mass, and it affords very striking testimony to the power of affinity to find that rocks which were once red are now white with the iron concentrated in nodules, sometimes many feet apart. An example of this may be seen on the shore opposite Corrie Hotel, where there is a thick white sandstone containing large irregular balls of red sandstone, 8, 10, and even 12 feet in diameter.

The hematites with which Arran abounds are, I believe, due to segregation. They sometimes occur as detached nodules, sometimes as nodular bands, and sometimes as regular bands, although these latter may simply be nodules closely packed together at their edges; but it is very striking to find these nodules in strata almost pure white, as if every atom of the iron had been attracted or drawn out of the stratum into the nodule. Good examples may be found in the old quarry immediately south of Corrie limestone quarry, from which the specimen exhibited was taken.

Another very striking instance is from Maoldon, in the hollow between the northern and the eastern cliff, where a bed of fireclay contains a seam of clay, or shale, from 2 to 3 inches thick, crammed with minute ironstone nodules, each nodule not half the size of an ordinary pin-head, yet regularly distributed through the clay. Where the surface has been exposed to weather these nodules may readily be separated from the matrix, and when seen in mass have somewhat the appearance of turnip seed. It is remarkable that while abounding in iron the shale should be nearly white, owing, I believe, to the whole of the iron having been removed through the strong attraction of segregation.

Mr. John Young, LL.D., F.G.S., about the same time discovered

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specimens of a similar kind at the north-east corner of Brodick Bay, about 2 miles south-east of the above-mentioned locality, though they differ considerably from the others. The Mill burn also carries down and deposits hematite iron, which on the lower part of its course is gathered by the natives and visitors, and used for reddening the doorsteps of their houses. Notwithstanding the difference of the specimens, I think that they are from a continuation of the same bed, as a considerable fault occurs between these parts, upthrowing the limestones and the accompanying strata.

And now, in conclusion, the question may be asked—Is there any way of accounting for the redness of the Arran rocks, so different in many cases from their equivalents elsewhere? The ironstones appear to have been deposited in a manner exactly similar to the clayband ironstones of the mainland, and I am strongly of opinion that originally they were similar, and that the alteration to peroxide of iron took place subsequent to their deposition and segregation, and was due to some cause which was local, and did not apply to the West of Scotland generally.

This cause might have been heat. The red rocks of Arran are situated round, and at no great distance from, a granite nucleus, upheaved to its present position subsequent to the deposition of the stratified rocks, and it is just possible that to the slow and long-continued baking to which they must have been subjected the alteration to red oxide, both in the ironstones and sandstones, is due. We know that clay assumes its red colour by firing, and, although a heat sufficient to burn a brick might destroy a fossil in the limestone or shale, yet that required to effect the change in colour may not have been so great if continued for a length of time. I throw out this suggestion with considerable diffidence, however, knowing it to be open to many and serious objections.

Since these remarks were penned, a curious circumstance, with a bearing on the point, has come under my notice. Some time ago, during excavations for a gasholder tank at Thornliebank works, the excavated material was carted and thrown down at Arden old limestone quarry. It proved to be a fossiliferous shale containing a large number of nodules. After lying for some time it took fire, and has been smouldering away for some months.

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The heat in the deeper parts was high, but on the surface much less—probably from 120° to 150° Fahr.—yet it has been sufficient to alter the colour of the nodules from bluish gray to red (as shown by the specimens exhibited, some of which contain fossils which have been altered, but not destroyed).

Another point is the condition of fireclays and shales charged with plant-remains, which, as an invariable rule, are black in colour. I think I am safe in saying that any such beds which are not so have been subjected to alteration. The effect of heat upon such material as clay or shale is to drive off the carbon and leave it whitish or (if it contain iron) reddish. Now, none of the fireclays among the red rocks of Arran are black. They are either of a creamy white or reddish colour, an alteration which, as I have shown, could have been, and probably has been, produced by heat.

Proceeding from observation and theory to experiment, I took some specimens of fireclay filled with small ironstone nodules, and of a dirty black colour, which had been found by Mr. J. B. Wise at Blochairn (in the north-east of the city), and put a piece into my parlour fire, heaping up coals over it. After about two hours' roasting it was found that the black colour had disappeared and that the fireclay had become whitish, very similar to some of the Arran fireclays, while the ironstone nodules had been altered to red and blue oxide. A second experiment on the same lines, the heat applied being less, gave better results, and the specimen looked as if it had come from one of the Arran beds.

NOTE.—At the close of the paper the Hon. Secretary (Mr. Murdoch) read the following telegram which he had received in the course of the evening from Sir Archibald Geikie, F.R.S. :—

"To Secretary, Geological Society,
"207 Bath Street, Glasgow,

"Statement about Arran limestones corrected. See *Annual* "*Report Science and Art Department*, 1894, p. 284. GEIKIE."

In the course of the subsequen discussion the author stated that up till the moment the telegram was read he was not aware that any corrections of the statements in the "Text book" had been published by Sir Archibald Geikie.

The Annual Report of the Science and Art Department, 1894, was received by the Mitchell Library, direct from the Department, on 5th September, 1895. This date may therefore be regarded as the date of its

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publication, and is long subsequent to the time when the notes were taken by the author for the foregoing paper.

The following extract is taken from Sir A. Geikie's report (p. 284) referred to above:—

Permian.—"The age of the red sandstones which extend along the eastern shore of Arran from Corrie to Brodick and thence across the southern half of the island, underneath the various sheets of eruptive rocks, has been much discussed.

"By Sedgwick and Murchison these strata were classed as New Red Sandstone, a view that was subsequently adopted also by Ramsay. Afterwards, however, Bryce and other writers placed them in the Carboniferous system and correlated them with the red sandstones of the north of Ayrshire and Renfrewshire.

"A re-examination of the ground was made by me last spring in company with Mr. Peach and Mr. Gunn. We found that pebbles of the Carboniferous Limestone with its characteristic fossils actually occur in the breccias at the base of these red sandstones between Corrie and the north end of Arran, as was first observed some years ago by Mr. James Thomson.[1]

"Closer inspection of the coast-sections and of the interior showed us that, besides this evidence of a decided stratigraphical break, the red sandstone, conglomerates and breccias lie unconformably on the Carboniferous formations, though at the actual junction the two series seem almost conformable.[2]

"It was thus manifest that these red sandstones could not be Lower Carboniferous, as had been supposed, but must be later than the Carboniferous limestone series. North of Corrie they rest on the uppermost members of the limestone series, or the base of the Millstone Grit. In the interior, at the head of Banlister Glen, they lie on the Corrie Limestone, hundreds of feet lower down in the Carboniferous system, while on the west coast at the mouth of the Machrie Water, they appear to come directly down upon the Old Red Sandstone, the whole of the Carboniferous formations having there disappeared.

"These upper unconformable, and overlapping red strata may be divided into two fairly well-marked sections, a lower group consisting of massive

[1] The above reference to Dr. Bryce is hardly correct, as he especially excepts the rocks near the north end of Arran from the other overlying red sandstones of the east and south. These latter he considers of Lower Carboniferous (*i.e.*, calciferous sandstone) age ("Geology of Arran," p. 15). The northern rocks he, however, considers to be Upper Carboniferous, as the following extract (p. 129) will show:—"These beds are the "uppermost members of the whole series, which begins to overlie the Old Red Sandstone "near the Fallen Rocks. From their position and mineral character they have been "classed as New Red Sandstone by Murchison, Sedgwick, and Ramsay. Mineralogically they have a much greater resemblance to Lower Permian strata than any of the "rocks in the southern district; but we refer them, notwithstanding, to the Upper "Carboniferous series, to which they are more closely related by their fossils."
I am not aware of any writer who classes these rocks as Lower Carboniferous.

[2] This stratigraphical break and unconformability appears to be a new discovery, and if satisfactorily established would dispose of my objections to regard these rocks as in other than their natural sequence. In that case the rocks above this break might very well be referred to the Permian. J. N.
June, 1896.

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false-bedded sandstones, varying from a bright brick-red colour to tints of yellow and grey, and an upper group of red marls and shales, containing thin sandstones and occasional thin seams of nodular limestone. The upper division extends through all the southern and a part of the western district of Arran, from Dippin round to beyond Drumadoon.

"No decisive evidence has yet been obtained to fix the geological age of this series of red strata. That they are probably Permian may be inferred on two grounds.

"In the first place the lower group of false-bedded brick-red sandstones presents the closest resemblance to the red sandstones which, within sight on the opposite mainland of Ayrshire, rest upon the Coal-measures and have been referred to the Permian period. In like manner, they resemble the red sandstones of the south of Ayrshire, Wigtownshire, and Dumfriesshire, which are also assigned to the same period.

"In the second place, the Arran red sandstones have been found by Mr. Gunn to enclose a contemporaneous volcanic group, a feature which is specially characteristic of the Permian series of the centre of Ayrshire and of Nithsdale."

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No. XXIX.—On the Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone. By Peter Macnair. With a Plate [No. VI.] and Illustrations in the text.

[Read 13th February, 1896.]

Introduction.—Ever since the publication of Mr. Harris Teall's description of the Scourie dyke, and its passage from a true basic igneous rock into a highly foliated schist by the ordinary processes of regional metamorphism, petrologists have turned their researches in that direction for a solution as to the origin of the hitherto little understood group of basic schistose rocks, such as hornblende schist, actinolite schist, or schists strong in some pyroxenic mineral.

Having lately paid some attention to these schists as they are developed in the Southern Grampians of Scotland, and more especially in that remarkable sill seen underlying the Loch Tay limestone, I thought I could not do better than bring before the members of this Society the observations I had already been enabled to make, and which I hope, in the course of next summer, to be able to considerably amplify.

Lately, while arranging the rock-specimens in the Museum of the Perthshire Society of Natural Science, I had occasion to pass through my hands a large series of these hornblende schists, from many different horizons in the Highland rocks. The strong external resemblance of these metamorphosed basic rocks to one another undoubtedly pointed to a community of origin; and while they mostly occur as sills intruded into different horizons of the Highland rocks, the probability is that the source from which they have all been derived is the same, and the sill underlying the Loch Tay limestone may therefore be taken as typical of the whole series.

Originally my intention was to deal with the gabbro and serpentine rocks, which also come under the category of altered basic rocks; but to these I can only refer at present, confining my attention principally to the hornblende schists.

I have here to thank Mrs. Fingland for her kindness in translating from the French and German, for my use, the views of

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EXPLANATION OF PLATE VI., VOL. X.

In illustration of Mr. Macnair's paper "On the Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone," page 302.

Fig. 1.—Section of Hornblende Schist, from Finlarig, near Loch Tay, Killin, as seen under the microscope. The main mass is made up of long green actinolitic needles of hornblende, with layers of water-clear grains of crushed felspar, opaque iron ores, and reddish garnet, the whole being arranged along the lines of schistosity in the rock.

Fig. 2.—Section of Porphyritic Hornblende Schist, from the Pass of Killiecrankie, as seen under the microscope. The dark-green ground mass is principally made up of long needles of actinolitic hornblende, through which are interspersed whitish spots—the representatives of the original felspar crystals—and still retaining the characteristic twin-striation. Crystals of secondary biotite, and occasionally of garnet, occur.

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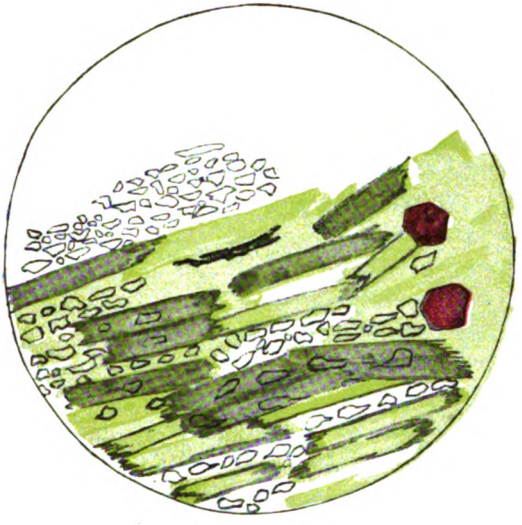

Fig. 1.

HORNBLENDE SCHIST.

Fig. 2.

PORPHYRITIC HORNBLENDE SCHIST.

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several of the Continental geologists on these rocks. Also, I have to thank Mr. James White for kindly lending me specimens from Argyllshire, and the Council of the Perthshire Society of Natural Science for the loan of one of their museum specimens.

History of Theories regarding the Origin of Hornblende Schist.—Amongst the schists and other altered clastic rocks of the Scottish Highlands which bear more or less evident marks of their original sedimentary origin, we find a series of schistose rocks whose origin has long been a subject of controversy, and whose exact nature and relationships have even yet not been fully disclosed. I refer to that class of rocks which has gone under the various names of hornblende rock, hornblende schist, primitive greenstone, and greenstone slate.

Maculloch, in his classification of rocks,* seems to have observed many of the distinguishing aspects of this rock, citing its occasional passage from the non-schistose to the schistose variety. He also notes that the former variety is always interstratified with the schistose one, and describes the association of hornblende schist and chlorite schist with many anomalous compounds. This would seem to point to some of those schists being interbedded, and the chlorite schists being the probable equivalents of contemporaneous volcanic tuffs. In speaking of its origin he says, 'Whatever appearance of a mechanical disposition may arise from the occasional laminar alternation of the ingredients of this rock, . . . it is barely necessary to observe that the texture appears to be truly crystalline or chemical in all the varieties, and that it has not hitherto presented anything containing, like micaceous schist, decided fragments of other rocks." He thus seems to have looked upon it as one of the primary chemical precipitates from a thermal ocean.

De La Beche† further maintains the existence of a thermal ocean to account for the origin of these rocks, and thus describes it—"A time, however, must have come in the earth's history when the heated rock would merely allow the water to remain liquid upon it, and there would be a condition of things in which a great mass of heated water existed on the face of the globe, which, driven off by evaporation, condensed in the atmosphere,

* "A Geological Classification of Rocks," p. 298.

† "Geological Researches in Theoretical Geology, p. 298, *et seq.*

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and fell again into the mass beneath. It was in this thermal ocean that such rocks as hornblende schist were deposited." He further remarks that many of the inferior stratified rocks have evidently been chemical deposits, and some perfectly resemble granite and greenstone divided into beds. Some beds of hornblende rocks differ little from beds of greenstone. We have had opportunity of seeing how both these kinds of rocks pass in their lines of strike or direction into common gneiss or hornblende slate with mica.

Sterry Hunt, in a later enunciation of this theory, says*—"As regards chemically-formed sediments, steatite, serpentine, pyroxene, hornblende, and in many cases garnet, epidote, and other silicated minerals are formed by a crystallisation and molecular re-arrangement of silicates generated by chemical processes in the waters at the earth's surface.

Darwin† also points out the passage of greenstone into a hornblende schist, but he regards the greenstone as being the type of extreme metamorphism.

Prof. Jukes‡ seems to have been the first to consider hornblende schist as being simply an altered tuff or basic lava and makes the following remarks:—"As far, indeed, as my own observation goes, I should doubt the existence of these rocks in any other form than as the result of a partial metamorphism of some hornblendic 'ash,' or of some mechanically-formed rock, derived from the wear and tear of a greenstone or a syenite."

Allport, Phillips, and Bonney, in our own country, and Lehmann, Lasaulx, and others on the continent,§ have contributed more or less to the theory that these schists are nothing more than metamorphosed basic igneous rocks.

The idea of the metamorphism of a truly igneous rock into a highly-foliated schist had thus been long suspected, but it was not till the publication of Mr. Teall's paper on the Scourie dyke‖ that it was finally shown in a particular instance, in two dykes intruded into the old archæan gneiss of Sutherlandshire an

* "Chemical Essays."

† "Geological Observations," 2nd ed., p. 432.

‡ "Students' Manual," p. 169.

§ For papers by these authors see *Quart. Jour. Geol. Soc.*, v.y.

‖ *Quart. Jour. Geol. Soc.*, vol. xli., p. 133.

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undoubted passage having been found from a crystalline dolerite into hornblende schist. The following may be taken as a summary of his conclusions:—(1) That the hornblende schist has been developed from a dolerite by causes operating after the consolidation of the dolerite, and that the metamorphism has been accompanied by a molecular re-arrangement of the augite and felspar; (2) That the molecular re-arrangement has in certain cases taken place without the development of foliation; and (3) That the plasticity which has led to the development of foliation is that due to high pressure at ordinary temperature.

Macroscopic Appearance.—In external appearance the rock is almost always black, or at least of a very dark green colour. The proportion of felspar—one of its principal constituent minerals—tends to modify the dark colour more or less, and, when present in considerable quantities, gives the rock a dark greyish hue. Mineralogically it is a compound of felspar and hornblende, which are its essential minerals; but sometimes the hornblende may occur alone, there being infinite variations of the proportions between the two minerals. The rock is generally schistose, occurring in well-marked laminæ of felspar and hornblende, but the degree of schistosity is very variable, passing from a high degree through numerous alternations to an entirely non-schistose variety—the primitive greenstone of early writers. Often the same bed will present in some of its parts one of these characteristics, while in another it will present that of an exactly opposite kind. The rock itself never forms large tracts in the Highland area, such as the clay slates, quartzites, or mica schists, but only occurs in subordinate beds alternating with some of the former rocks. Though the beds are thus of moderate depth (the sill underlying the Loch Tay limestone being estimated at 200 feet in thickness), their extension along the line of strike or outcrop of the beds is often very persistent. The hornblende schist commonly partakes of the contortions into which the other beds have been thrown, being bent and twisted in a similar way. It is always traversed by the granites and later intrusive igneous rocks of the Highlands, thus showing its anterior origin.

The two principal varieties are amphibolite or hornblende rock, the name being sometimes applied to the unsheared variety, and

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actinolite schist, which is characterised by the presence of that mineral instead of the ordinary hornblende.

The principal accessory minerals are pyrites and garnet, the latter sometimes occurring in quantities sufficient to modify the appearance of the rock. It is sometimes more or less perfectly crystallised as it is in mica-schist. In some rare cases, it is disposed in laminæ amongst the hornblende.

Occasionally these schists show evidence of having been developed from a rock which had originally been highly porphyritic in character, the porphyritic felspar crystals being still recognisable, though now drawn out into long, more or less parallel, lines of shear. The original forms of the crystals have been, however, entirely lost, their faces having been completely rounded off during the process of the mechanical deformation of the rock. Microscopically these eyes of felspar have more the appearance of pseudomorphs, being partly replaced by hornblende and the other mineral constituents of the rock, but to this point I shall revert later on.

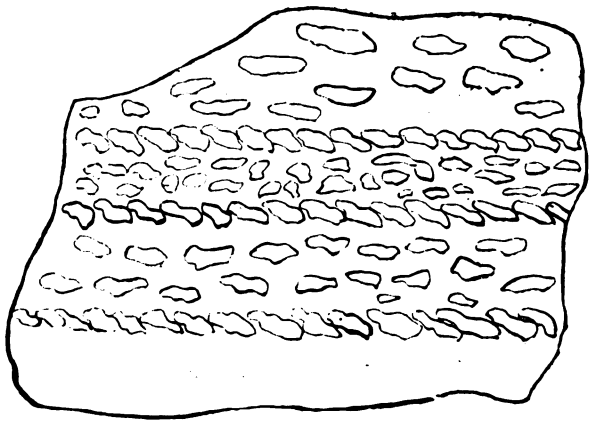

Fig. 1.
Porphyritic Hornblende Schist.

Fig. 1 is a diagrammatic representation of a hand specimen of this porphyritic hornblende schist, the lines of porphyritic crystals showing the effect of the shearing process in re-arranging the original structure of the rock-mass.

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Many of these schists show an extremely fine contorted, and foliated structure. In one hand specimen quite a series of these folds may be seen in the space of a few inches, it being equally as finely foliated and corrugated as any piece of typical mica-schist. In other cases the foldings are larger. In one very fine specimen from the Loch Tay sill a piece of the original igneous or crystalline rock has been bent round into a perfect miniature syncline, or anticline, showing a completely schistose structure, the whole specimen measuring about 2 inches long by about $1\frac{1}{2}$ inch wide.

One of the most interesting of all the specimens is that from the Loch Tay sill where it comes to the surface in Glenlyon. The rock shows not only a highly foliated structure, but also a series of banded layers of felspar and hornblende. Now, when we consider that this banded structure (which would be quite easy of explanation in a clastic rock) belongs to what must have been at one time a basic igneous rock of ordinary crystalline texture, the problem of the banding becomes more difficult of solution. Mr. Teall, in a paper "On the origin of certain banded gneisses," proposes to account for the origin of a banded structure in a rock originally crystalline. He there shows* (1) that banded gneisses are on the whole identical with plutonic rocks in composition; (2) that masses of plutonic rocks are often heterogeneous; and (3) that heterogeneous masses, if such exist, may be deformed in the manner required to produce banded structures. He illustrates his case experimentally by showing how that if two pieces of differently-coloured clays be mixed up together and then drawn out to imitate a shearing process, folded over and then drawn out again, a perfect banded structure will be produced in the clay. He sums up by saying—"It may be a long time before we become acquainted with the precise nature of the movements and deformations, but that they are adequate to convert a heterogeneous mass into a banded gneissic series is, to say the least, highly probable." My own opinion is that these banded structures in the hornblende schist are probably referable to a somewhat similar process to that brought forward to account for the banded gneisses of the Lizard district by Mr. Teall.

Fig. 2 is a diagrammatic representation of a hand specimen of

Geological Magazine, 1887.

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banded hornblende schist from near Cashlie in Glenlyon, the dark banding being mainly composed of long prisms of hornblende arranged according to the general schistosity of the mass, while the white bands represent layers of felspar.

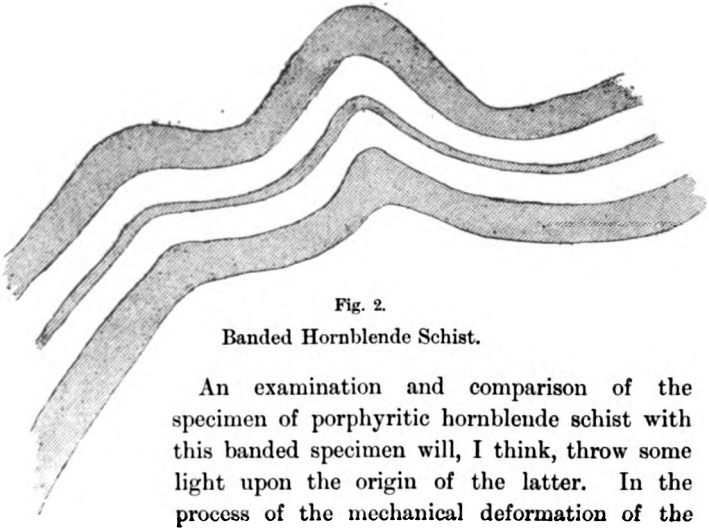

Fig. 2.
Banded Hornblende Schist.

An examination and comparison of the specimen of porphyritic hornblende schist with this banded specimen will, I think, throw some light upon the origin of the latter. In the process of the mechanical deformation of the original crystalline rock the porphyritic crystals of felspar are seen to be arranged in linear streaks parallel to the general schistosity of the rock. Now, I do not think it would be difficult to imagine how, under certain conditions, this porphyritic hornblende schist would pass into a truly banded type, as seen in the specimen from Glenlyon. The existence of the felspar crystals fulfils the conditions of making it a heterogeneous mass, and I should look upon the banded specimen as a further deformation of such a rock as the porphyritic hornblende schist.

Microscopic Structure.—Passing now to a consideration of the microscopic structure of these rocks, they are shown, under a low power, to be built up of alternating foliæ of light and dark material, which, with an increased power, are resolved into layers of felspar and hornblende. The felspar has, in every instance I have examined, except in the case of the porphyritic hornblende schist, entirely lost its original structure, and has become deformed by the breaking up of the original felspar crystals into a finely granular mass.

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The grains of felspar, with which may also be associated some quartz, are in most instances perfectly water-clear, and, so far as the rock structure itself is concerned, have more the appearance of a clastic rock, such as quartzite, than of an originally crystalline mass. So complete is this simulation of a clastic rock that it deceived for a considerable time not a few experts in petrology.

In the porphyritic hornblende schist the large crystals of felspar do not seem to have suffered so much as those in the ordinary types of the rock, parts of them being altered to a perfectly water-clear ground mass in which are imbedded grains of felspar and hornblende. Portions of them, however, seem to have escaped this deforming process, and still retain the original twin striations so characteristic of the plagioclase felspars, and even in some instances, I believe, the form of the crystal itself. These grains of felspar show a distinctly parallel or linear arrangement along the lines of shearing in the rock, the longer axes of the grains generally all lying in the same direction. The hornblende occurs as long needle- or prism-shaped forms in thin sections showing a bright green colour passing into brownish shades, the latter probably owing to weathering. As a rule, the longer diameter of the needles or prism-shaped forms lies parallel to the plane of schistosity. On rotating the polarizer the hornblende displays a marked orientation.

In a paper "On some schistose greenstones and allied hornblende schists from the Pennine Alps as illustrative of the effects of pressure metamorphism,"* Prof. T. G. Bonney refers (in a foot note) to the occurrence of this Scottish porphyritic hornblende schist. He says—"Since the above paper was written I have obtained additional evidence from Scotland. In the Pass of Killiecrankie dioritic dykes, more or less schistose, are frequent, some of which present interesting resemblances to certain of these alpine hornblende schists. The rocks can be examined *in situ*, close to the Garry, and occur as boulders in its channel. They are more or less foliated, evidently sometimes containing biotite, and not unfrequently red garnet. Occasionally the former presence of a porphyritic felspar is indicated by white spots. In other parts of the same mass garnets are abundant. (I have long suspected that most eclogites are diorites in which

* *Quart. Jour. Geol. Soc.*, 1893.

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garnet has taken the place of felspar.) I have examined microscopically one of the less foliated examples from a dyke above the bridge in the village, and the most foliated one from a boulder. Both, especially the latter, strikingly correspond with some of the rocks described in this paper, the hornblende occurring in dark green prisms with enclosures evidently of later date than that of the principal crushing—the biotite being newer than the hornblende and sometimes suggesting pseudomorphic replacement, and the garnets being anterior to the crushing."

Mr. Teall* thus describes a porphyritic hornblende schist or porphyritic epidiorite which he supposes to have been originally a porphyritic dolerite—"In thin sections the ground mass of the rock is seen to consist of long actinolitic needles, water-clear grains of felspar, and grains of leucoxene. The needles are arranged approximately parallel to each other in the plane of schistosity (direction of stretching). The water-clear substance is certainly in many cases biaxial, and therefore may with considerable confidence be referred to felspar. It may be said in a certain sense to play the rôle of ground mass, for actinolitic needles often lie imbedded in it. Grains of a nearly opaque substance, in part brown granular sphene, evidently represent the iron ores of the original rock. The eyes of the schist are turbid felspar pseudomorphs similar to those which occur in the epidiorites. Their angles have, however, been completely rounded off." Thus this description of the hornblende schists of the Lizard exactly corresponds with those from the Highland area which we are now considering.

To what species of the basic igneous rocks these hornblende schists may have originally belonged it is now difficult to say. The presence of porphyritic crystals of felspar still showing the characteristic twin striation of the plagioclase group and the large percentage of hornblende in the schist, which has been shown to have an intimate relation with augite, would lead us to infer that the rock had originally been intruded as some variety of diabase lava. Some of these hornblende schists may be allied to the gabbros which are also found as intrusive sills in the Southern Grampians, as in Glen Quaich near Crieff.

**Proceedings of Geologists' Association*, "Excursion to Cornwall," August, 1887, p. 41.

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Dr. Lehmann has described many instances of the passage of a gabbro into a hornblende schist in the granulitic region of Saxony by powerful mechanical strains, and Teall has applied the same explanation to the gabbros of the Lizard, showing how the original rock, composed of labradorite or bytownite has passed with the development of foliation into a schist, the felspar passing into saussurite and the augite into hornblende.

Geological Distribution and Mode of Occurrence as exemplified by the Loch Tay Sill.—Before passing to a description of the particular bed of hornblende schist which underlies the Loch Tay limestone, and which we propose to take as an illustration of its mode of occurrence in the Highlands, we shall briefly revert to the structure of the latter—and the general distribution of these sills of hornblende schist through the undoubted clastic rocks.

We have proposed to group the altered clastic rocks* of the Southern Grampians in the following order, beginning with the uppermost and youngest members of the group:—

1. The Upper Arenaceous zone.
2. The Upper Argillaceous zone.
3. The Middle Arenaceous zone.
4. The Loch Tay Limestone zone.
5. The Lower Arenaceous zone.
6. The Lower Argillaceous zone.

The lowest member of the series is that well-known band of clay-slate which passes from shore to shore of the island, outcropping at the southern verge of the Highlands. The next above, or Lower Arenaceous zone, is composed of a massive series of grits, greywackes, and conglomerates, well seen in Ben Ledi, the Pass of Leny, and Ben Vorlich. According to Sir Archibald Geikie and his colleagues of the Geological Survey, it is at the top of this group that hornblende schists first appear in the Highland rocks. Passing upwards into the Middle Arenaceous zone they become quite common, being well seen in the massive sill underlying the Loch Tay limestone. In the Upper Argillaceous zone and Upper Arenaceous zone hornblende schists are also locally abundant. It seems, then, they are to be found more or less commonly in all the zones, excepting the Lower Arenaceous and Lower Argillaceous group. How they should be absent from these latter, more especially

*For a detailed account of these rocks see a paper by the author in the *Geological Magazine*, 1896, pp. 167 and 211.

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when they are considered to be as originally of intrusive character, is a problem I am unable to solve.

Intercalated in our Middle Arenaceous zone is a series of bands of limestone and calcareous mica-schist, to which has been given the name of the Loch Tay Limestone zone from its great development in that district. On the north side of Loch Tay this band of limestone is seen to come to the surface at Killin, being well seen in a bold escarpment on the south front of Sron Clachan, crossing underneath the eastern slope of the latter mountain. It has been levelled down by the passage of the river Lochy into Loch Tay, but again rises in extensive precipices in the woods of Finlarig, from which it passes north-eastwards in a straight line along the bases of Meal na Tarmachan, Ben Glass, and Ben Lawers, to Fernan, where it is cut off by a powerful fault. The limestone dips underneath the group of mountains forming the northern sides of Loch Tay at an angle of about 45° to the north-west.

On the south side of the loch the limestone is seen high up on the side of Ben Leithan, from which point it may be traced round to the head of Glen Ogle, where it will be found near the old Killin junction. Passing down Glen Ogle, the limestone may be observed at various points, till, on reaching Loch Earn, it curves round to the east, again being well exposed in Dalveich quarry. From this point it extends north-eastwards up Glen Beich into the basin of the Tay again. An isolated outlier of the Loch Tay limestone is also seen to cap the top of Meal na Creig, a mountain 2683 feet high, on the south side of the loch.

I have thus somewhat minutely defined the range of the Loch Tay limestone, because it is a singular fact that wherever it outcrops to the surface it is found to be followed by a band of hornblende schist. In the Finlarig woods at Killin, and on the pier road there, some very fine sections of the hornblende schist and limestone in actual contact are to be found. So close and so well defined is this line of contact that the blade of a pocket knife could be inserted between the two rocks. This band of hornblende schist is seen to follow the limestone in its course along the north side of Loch Tay, as already described. On the south side of the loch a similar occurrence of limestone and hornblende schist is to be seen. Tracing them down Glen Ogle, the limestone and the

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hornblende schist are found outcropping together in the bed of a stream a little to the north of the Glen Ogle toll-house. Passing round into the valley of the Earn a very fine section of the hornblende schists and the limestones are exposed at the foot of Glen Beich, the contact of the two rocks being traceable right to the head of that glen and back into the valley of the Tay. Underneath the outlier of limestone on the summit of Meal na Creig the hornblende schist is also seen.

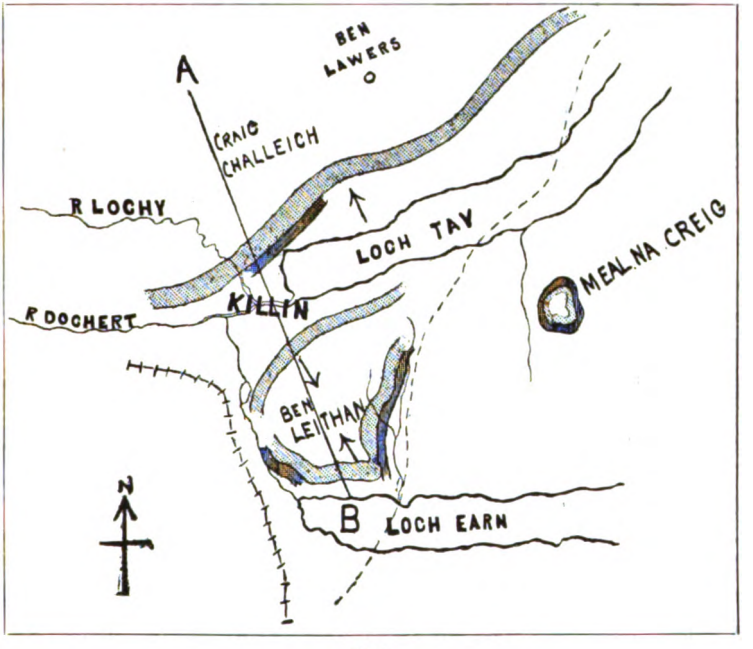

Fig 3.
Sketch Map of the Loch Tay District.

In the map of the Loch Tay district (fig. 3) and accompanying section (fig. 4, see p. 314), the light band represents the outcrop of the limestone, while the darker band is that of the hornblende schist outcropping at the base of the former wherever it is exposed.

Sir A. Geikie, speaking of this sill in his Presidential Address to the Geological Society of London,* says—"Over wide tracts of the central and south-western Highlands, and of Donegal, some of

Quart. Jour. Geol. Soc., 1891.

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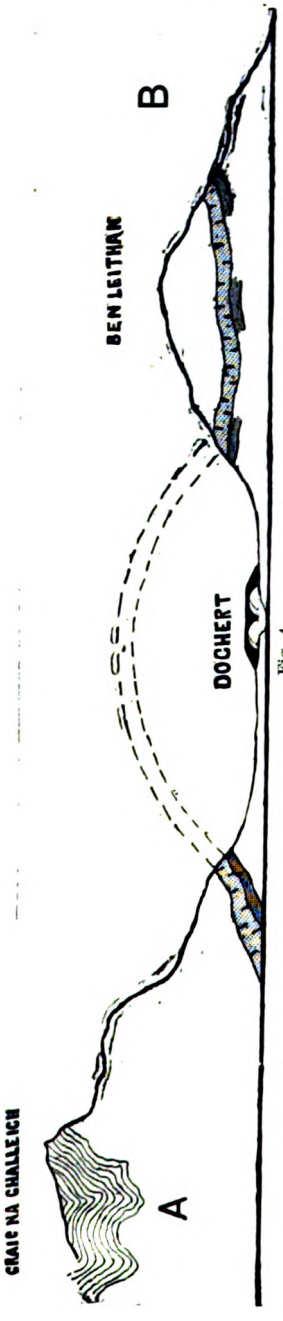

Fig. 4.
Section along the line A B in Map [see fig. 3 on previous page].

the most marked and persistent rocks are sheets of diorite, epidiorite, and hornblende schist, which were erupted as molten materials, not improbably as varieties of diabase lava. Most of these sheets are doubtless intrusive sills, for they can be observed to break across from one horizon to another. But some of them may possibly be contemporaneous lava streams.

A sheet may sometimes be traced for many miles occupying the same stratigraphical platform. Such hornblendic rocks occur on many horizons between the great band of Ben Vorlich grits and the Ben-Y-Gloe quartzite. One of the most marked of these is a sill, sometimes 200 feet thick, which underlies the Loch Tay limestone. In Argyllshire also an abundant series of sheets of epidiorite, amphibolite, and hornblende schist runs with the prevalent strike of the schists, grits, and limestones of that district, while similar rocks re-appear in a like position in Donegal. The frequency of the association of these eruptive rocks with the limestones is worthy of remark.

It might be inferred from the manner in which this bed of hornblende schist comes so constantly to the surface with the Loch Tay limestone that it must have originally been a contemporaneous bed of igneous rock rather than an intrusive sill. But in various sections, and more particularly in that exposed near Killin, at Finlarig, the hornblende

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schist undoubtedly transgresses the beds of limestone, the latter being baked and altered in the manner characteristic of contact with an intrusive rock.

Time will not now permit of my entering into the problem of the manner in which these sills of intrusive igneous rock attack and keep so constantly to one stratigraphical horizon. That they are capable of doing so is, however, well known—a more recent instance being the remarkable whin-sill of Teesdale, Northumberland, of which Messrs. Topley and Lebour have demonstrated the undoubted intrusive origin. The process may be chemical as well as mechanical, the intrusive mass gradually replacing the invaded rock by chemical assimilation; and, if the fact be true, it may also account for the manner in which these hornblende schists are so often associated with the limestones.

On the Deformation of a Petrological Complex by Dynamic Metamorphism and the Alteration of its Igneous Rocks into Schists.—Let us now glance briefly at the nature of the processes which were at work in altering these basic igneous rocks into schists. As you are well aware, the Highlands of Scotland are mainly built up of a great series of sedimentary rocks, in which shales have been altered into slates, phyllites, and sericite schists; sandstones, grits, and conglomerates into quartzites, and highly indurated representatives of the latter two rocks; limestones into marbles, and so on.

New structures have been developed in the old rocks; planes of schistosity are conspicuous, along which the mineral ingredients of the rocks have arranged themselves in foliæ. Other structures, depending on whether the rocks have simply been sheared by an equable stretching force, or whether they have been driven forward with a differential motion (as in the north-west of Sutherlandshire), have been developed.

An area such as the Highlands of Scotland may be looked upon as a petrological complex in which, prior to its metamorphism, all kinds of igneous and aqueous rocks were represented, just as an Old Red Sandstone and Carboniferous series, with their associated igneous rocks, are to be seen at the present day. But owing to earth-strains these originally horizontal rocks have been plicated and corrugated into folds graduating from synclines and anticlines, miles in width, down to the finest curves to be seen in a hand specimen. A metamorphic area is simply a petrological complex

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upon which a universal foliation has been super-induced by shearing. This foliation generally lies parallel to, or is related to, the direction in which its component sheets of rock have been plicated and piled up.

This specimen of greywacke will illustrate very forcibly the nature of these shearing forces which have operated in deforming the rock from its original structure. Originally an argillaceous or felspathic sand, it was burrowed into by worms, much as they do at the present day on the seashore. After the sand had been hardened into sandstone the rock became subjected to powerful earth-strains, the consequence being that the burrows, originally cylindrical, were deformed into ovates, and in extreme cases into ribbons or mere linear streaks. The crystalline and intrusive sills of diabase lava, which we believe these hornblende schists to have at one time been, were acted upon in a similar manner, undergoing both a chemical and a mechanical change in their mineral constituents.

It has been shown by several authorities, more especially by Irving and Williams, that augite is a very unstable mineral, and that it will readily become altered into hornblende; Mr. Williams supposing that the enormous pressures supplied in the process of mountain-building would supply these conditions, the augite thus passing into hornblende. The exact chemical changes in the felspar consequent upon these crushing forces are more difficult to understand, but, as Teall remarks, it seems to have passed into saussurite. The mechanical deformation, as you will have seen, is similar in many respects to that observable in the clastic rocks. The felspars have been broken up and drawn out into roughly parallel grains, and the augites into long needles or prisms of hornblende.

Summary.—To sum up, I have shown (1) that these hornblende schists were originally intruded as sills of igneous rock into the clastic rocks at a period prior to the metamorphism of the latter.

(2) That though difficult to state exactly, it is probable that the hornblende schists belonged to some variety of diabase lava originally containing augite, and a triclinic felspar, with iron ores.

(3) That subsequent to their intrusion, and during the great period of regional metamorphism which affected the Highlands, these lavas underwent a profound change.

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(4) That the original felspars were crushed and broken into water-clear grains having all the appearance of a clastic rock, while the augite was drawn out into long slender needle-shaped forms or prisms—a thorough foliated or schistose structure being superinduced upon the rock, and thereby converting what was originally a crystalline igneous rock into a schist.

NOTE.—Since the above paper was written I have again had an opportunity of examining the outcrop of these altered basic rocks on the summit of Meal na Creig, above the village of Ardeonaig, on the south side of Loch Tay. The rock outcropping at the base of the limestone outlier, as seen on that mountain (see Sketch Map of Loch Tay, page 313), does not show such a highly foliated structure as that seen in the sections at Finlarig and Sron Clachan, near Killin, and in Glen Beich, near Dalveich. Viewed microscopically, the Meal na Creig rock approaches more closely to the gabbros of Glen Quaich, and may probably represent an intermediate stage in the passage of the latter into a typical hornblende schist. It seems to me that the presence of garnet in these rocks may be taken as a criterion of the amount of change they have undergone. They finally pass into a true eclogite, which may therefore be taken as the extreme type of metamorphism to which these originally igneous basic rocks have been subjected.

June, 1896.

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No. XXX.—On the Discovery of Fossil Microscopic Plants in the Fossil Amber of the Ayrshire Coal-field. By John Smith. With a Plate [No. VII.].

[Read 12th April, 1894.]

Some fifteen years ago I began to find small pieces of amber (Middletonite) in coal brought from the Kilmarnock district, and immediately afterwards both in the coal and coal-shale of the five-quarter seam at the Misk pit near Stevenston. Subsequently I got some specimens of it from Mr. David Beveridge, then manager of the Annandale Colliery near Kilmarnock, who obtained it in the main coal seam.

This substance occurs in flattish blebs, from pieces little bigger than mouse-peas up to slightly over an inch in diameter, and in thin sheets, sometimes as much as two inches long, interbedded between the layers of the coal.

It agrees in character and occurrence with the description of Middletonite given by Dr. Page in his "Handbook of Geological Terms," as follows:—"A mineral resin found in the older coal formations and occurring in layers or in rounded pea-like masses of a reddish-brown colour, resinous, brittle, and easily sectile. So called from Middleton Colliery, near Leeds, where it was first discovered between the layers of the coal. Consists of 86 carbon, 8 hydrogen, and 5·5 oxygen." Amber has got 70 carbon, 12 hydrogen, and 8 oxygen, so that the Middletonite, before it lost some of its hydrogen and oxygen, may have been at one time identical in composition with the more recent amber.

The Misk variety, in thin transparent sections, is pale yellow in colour, the Annandale variety being somewhat reddish, while thick bits of both kinds are perfectly opaque.

The Kilmarnock main coal is the equivalent of the five-quarter coal at Misk, and I have reason to believe that my first Kilmarnock specimens came from the same seam.

In the West Ayrshire coal-field there are nine workable seams below the five-quarter coal (not including the lower Dalry coals), but in these I have never seen a single particle of amber (here so called for convenience sake), so that the "amber-weeping tree" was either not introduced into the area where these coals were formed, or had not been sufficiently developed before the period of

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the five-quarter coal seam. It is not in the meantime known what kind of tree it was, but in all probability it was a conifer (a pine or fir).

Having been collecting this fossil amber for a number of years past in the hope of finding insect remains, I prepared some fifty transparent microscopical sections, but did not find the remains of a single insect in any of them. I was, however, amply rewarded in discovering about twenty species of microscopical plants, and the male flowers and pollen of, perhaps, the tree that "wept" the amber. These plants belong to, probably, three orders of vegetation, coniferæ, confervoidæ (ord. nov.), and fungi, and are as well preserved as similar structures recently mounted in balsam. Having mentioned my discovery to Professor King of Glasgow, he seemed doubtful that such a delicate substance as pollen could be preserved in so old a formation as the Carboniferous. I sent him a slide of the amber with pollen in it, and received from him a note to say that the pollen was in perfect preservation.

The following is a list and description of the plants I have discovered in the amber (see Plate VII.):—

CONFERVOIDÆ, ord. nov.—These plants closely resemble *Confervæ*, but they want the "articulations."

1. *Sphairanema* curta*, gen. et sp. nov.—Minute short plants, with a single filament, springing from a globe (sometimes compressed, or oval), and having short branches placed alternate, and at right angles to the filament. Filament the two-thousandth of an inch in diameter. Globe the hundredth of an inch in diameter. Locality, Annandale (main coal seam), near Kilmarnock.

2. *Sphairanema plana*, sp. nov.—Similar to the last, with the exception of the branches. Locality, Annandale.

3. *Sphairanema Miskensis*, sp. nov.—Filament simple, swelling into globe-like beads placed at two to four diameters apart. Whole plant covered with minute punctures. Filament the two-thousandth of an inch in diameter. Locality, Misk (in the five-quarter coal and coal-shale), near Stevenston.

4. *Sphairanema Ayrshirensis*, sp. nov.—Filament with globes placed at two to three diameters apart. Simple branches springing in an alternate manner from the globes. Filament the fifteen-hundredth of an inch in diameter. Globes one-thousandth of an inch in diameter. Locality, Misk.

* A thread with globes.

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5. *Sphairanema clavata*, sp. nov.—Somewhat similar to the last, with a club-shaped end terminated by minute filaments. Globes one-hundredth to one-thousandth of an inch in diameter, increasing in size as they recede from the club-shaped end. Filament the three-thousandth of an inch in diameter. These plants are individually surrounded by smoke-like clouds. Locality, Annandale.

6. *Sphairanema tenuis*, sp. nov.—Plants very slender. Globes placed at three to five diameters apart. Filament the five-thousandth of an inch in diameter. Globes the fifteen-hundredth of an inch in diameter. Locality, Annandale.

7. *Sphairanema* (*?*) *spinulosa*, sp. nov.—Globe (elongated) the thousandth of an inch wide, covered with spines or short branches. As there is no filament to this one the genus is uncertain. Locality, Misk.

8. *Sphairanema monilifera*, sp. nov.—Minute beaded filaments, the globes being placed close together, and the three-thousandth of an inch in diameter. Locality, Annandale.

9. *Nemaplana** *filiforme*, gen. et sp. nov.—Filament simple, the three-thousandth of an inch in diameter. Locality, Annandale.

10. *Nemaclada*† *alternata*, gen. et sp. nov.—Filament branching alternately, the three-thousandth of an inch in diameter. Locality, Annandale.

11. *Nemaclada dichotoma*, gen. et sp. nov. — Filament dichotomous, the three-thousandth of an inch in diameter. Locality, Annandale.

12. *Nemaclada pulvifera*, sp. nov.—Filaments branching and rising into swellings along the sides, two- to three-thousandth of an inch in diameter. Looks as if it had been dusted all over; perhaps fruiting? Locality, Annandale, abundant.

13. *Nemaclada contorta*, sp. nov.—Filaments very much twisted, branching, the two-thousandth of an inch in diameter. Locality, Annandale, abundant.

14. The same species fruiting. Locality, Annandale.

15. *Nemaclada Beveridgei*, sp. nov.—Filaments smooth branching, fruiting, the twenty-thousandth of an inch in diameter. Fruit oval, the twelve-thousandth of an inch wide. I have named this

* A plain thread.
† A branching thread,

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species after Mr. D. Beveridge, to whom I am indebted for some bits of the amber. Locality, Misk.

16. *Sphairanema filiformis*, sp. nov.—Filament simple, with a few very minute filaments springing from it at intervals; swelling, the swellings being covered with a few very minute filaments. Filament the five-thousandth of an inch in diameter; swellings one-thousandth of an inch wide. Locality, Annandale.

MICRO-FUNGI.

17. *Peronosporoides Carbonifera*, gen. et sp. nov.—I see little difference in this minute plant from recent *Peronospora* (or *Mould*). From the top of a filament a very minute branching filament springs, which branches again, the latter branches being, generally speaking, placed at right angles. Large filaments the two-thousandth of an inch, small ones the twenty-thousandth of an inch, in diameter. Locality, Annandale.

18. The same species fruiting, the round fruit being the two-thousandth of an inch in diameter. Locality, Annandale.

19* and 19a. *Leptonema* † *tenuis*, gen. et sp. nov.—A much-branching form, generally springing from a shred of vegetable matter. Branches the forty-thousandth of an inch, covered with darkish globular fruit the twenty-thousandth of an inch in diameter. These minute plants appear like leafless apple-trees embalmed in the amber. Locality, Annandale.

ORDER UNCERTAIN.

20. *Carbonacarpa* ‡ *Annandalensis*, gen. et sp. nov.—Seed-like objects, about twice as long as broad, with minute ovo-cellular surface. One-thousandth of an inch wide. Locality, Annandale.

21. Globular objects, with minute, curved short lines over their surfaces. The two-thousandth of an inch in diameter. Found in myriads in the amber.

22. Oval-shaped bodies, the eight-thousandth of an inch to the ten-thousandth of an inch in diameter, with a bar crossing the middle. Found in myriads.

23. Similar to No. 22, but with the bar crossing obliquely. About the same size as last. Found in myriads.

24. Spores of Fungi, the twenty-thousandth to the thirty-thousandth of an inch in diameter. Found in myriads.

* No. 19 is drawn as seen from above.

† A slender thread.

‡ Coal fruit.

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25. Numerous husk-like objects—some very minute, some comparatively large. The smaller ones found in myriads. (Not figured.)

CONIFERÆ (?).

26. Portions of the male flowers of coniferous (?) trees. (Not figured.)

27. Pollen grains of coniferous (?) trees. Found in myriads. (Not figured.)

NOTE.—From the Carboniferous formation of Western Scotland four species of coniferous trees have been determined.

As to fossil Confervæ, Phillips in his "Manual" informs us that confervoidal cavities occur in soft yellow limestone in the Nettlestone Grits, Oligocene formation, Isle of Wight, and three species of *confervites* are known, one from the Lower Greensand and two from the Upper Chalk.

I do not know that remains of microscopic Fungi, or of tree pollen, have been found in a fossil state before, although one would think they would probably occur in ordinary amber, which is found in a much more recent formation than the Carboniferous.

FOSSILS IN CARBONIFEROUS AMBER, AYRSHIRE.

Explanation of Plate VII.

1. Sphairanema curta, *gen. et sp. nov.*
2. Sphairanema plana, *sp. nov.*
3. ,, Miskensis, *sp. nov.*
4. ,, Ayrshirensis, *sp. nov.*
5. Sphairanema clavata, *sp. nov.*
6. ,, tenuis, *sp. nov.*
7. ,, (?) spinulosa, *sp. nov.*
8. Sphairanema monilifera, *sp. nov.*
9. Nemaplana filiformis, *sp. nov.*
10. Nemaclada alternata, *gen. et sp. nov.*
11. Nemaclada dichotoma, *sp. nov.*
12. ,, pulvifera, *sp. nov.*, fruiting?
13. Nemaclada contorta, *sp. nov.*
14. ,, ,, fruiting?
15. Nemaclada Beveridgei, *sp. nov.*
16. Sphairanema filiformis, *sp. nov.*
17. Peronosporoides Carbonifera, *sp. nov.*
18. Peronosporoides Carbonifera, fruiting.
19. Leptonema tenuis, *gen. et sp. nov.*, fruiting.
20. Carbonacarpa Annandalensis, *gen. et sp. nov.*
21. ? Abundant in parts of the amber.
22. ? Abundant in parts of the amber.
23. ? Abundant in parts of the amber.
24. Spores of Fungi (?). Abundant in parts of the amber.
25. Part of male flower of a Conifer?

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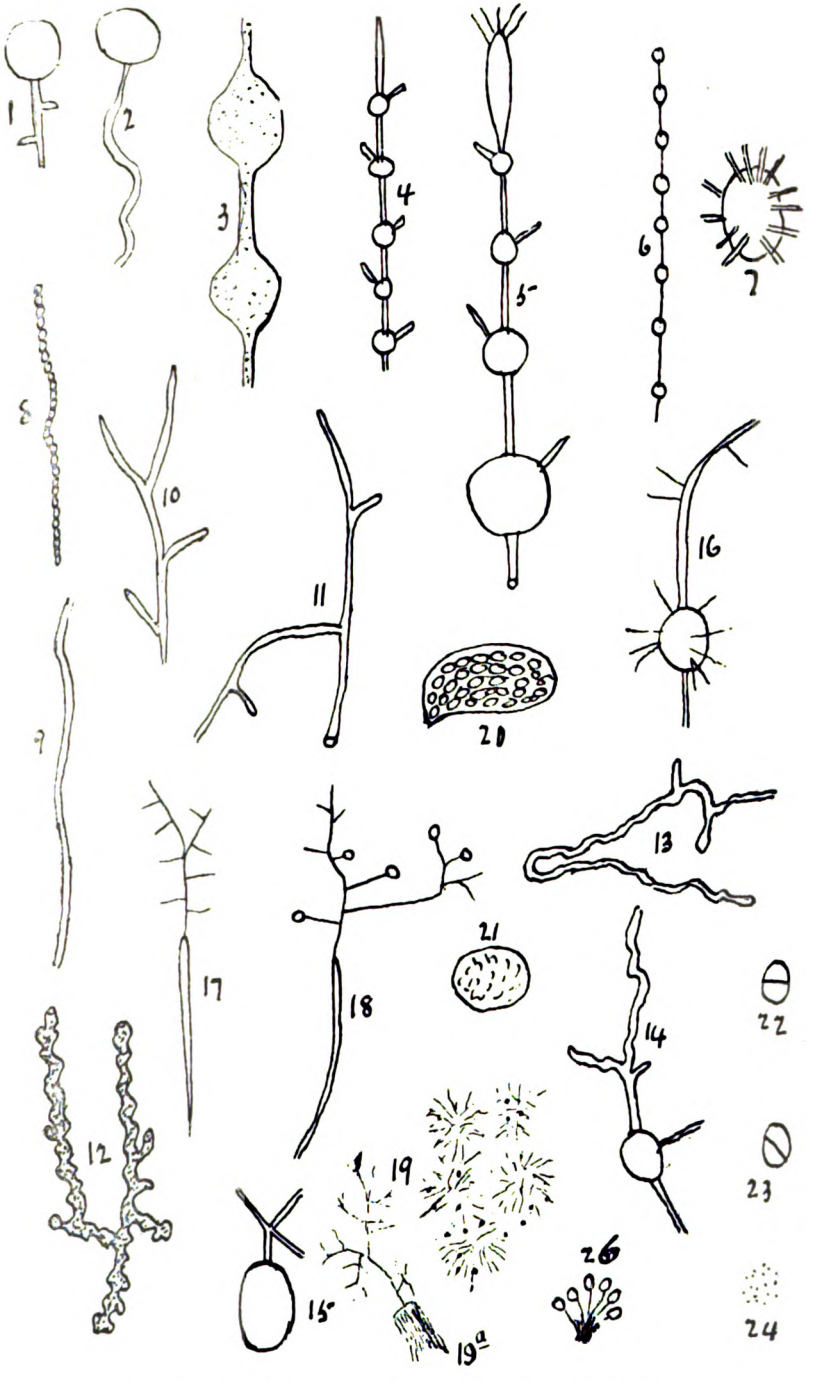

MICROSCOPIC PLANTS IN AMBER (Middletonite) FROM COAL.

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No. XXXI.—On the Genera *Lycopodites* and *Psilophyton* of the Old Red Sandstone Formation of Scotland. By James Reid and Peter Macnair. With Three Illustrations.

[Read 9th April, 1896.]

Towards the close of the Upper Silurian period certain traces of land plants appear, but in the flora of the succeeding Devonian period we find a more exuberant and varied representation of the earliest terrestrial plants which occur in the stratified rocks of the globe. The Devonian flora of Scotland, like that of Central Europe, is met with in an obscure and imperfectly preserved condition. It is in the sandstones of Gaspé and New Brunswick where the plants which it comprises more abundantly occur. Sir William Dawson refers to the occurrence in the Devonian of North America of upwards of a hundred species of plants, showing in some instances fruit and internal structure in a very perfect state of preservation.*

Before discussing the affinities of *Psilophyton* and *Lycopodites* as typical plants of the period the stratigraphical position and relationships in the Old Red Sandstone assigned by geologists to the deposits of Midland Scotland, and those of the Caithness area, may be briefly adverted to.

Sir R. I. Murchison held that the three groups of the Devonian system represent the Lower, Middle, and Upper divisions of the Old Red Sandstone—the Lower occurring in Forfarshire, and the Middle in Caithness.†

Sir A. Geikie, however, dissents from this view, and classes the deposits of Midland Scotland and those of the Caithness area into Lower and Upper Old Red Sandstone.‡ From a stratigraphical point of view this classification apparently leaves little to be desired, but an examination of the palæontological evidence shows that the facts are not strictly in accordance therewith. He dwells strongly upon the occurrence of *Pterygotus*, *Acanthodes*, *Psilophyton* (and we might add a recent find of *Cephalaspis* in the Caithness flags),§ in the northern and southern areas as proofs of

* "Geological Survey of Canada," 1871.

† "Siluria," 3rd ed., 1859, p. 284.

‡ "The Old Red Sandstone of Western Europe," *Transactions Royal Soc., Edin.*, vol. 28, part I., 1879, pp. 361-362.

§ *Annals of Scottish Natural History*, 1893, pp. 206-207.

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contemporaneity; but the scanty remains of *Pterygotus* and *Cephalaspis* met with in the Caithness flags apparently indicate a life verging upon extinction and a period later in time. The evidence derived from the occurrence of acanthodian fishes in the northern and southern areas becomes of minor importance when we know that the acanthodians range upwards through the Old Red and Carboniferous formations into the Permian. Again, we find that *Psilophyton* occurs in the Lower, Middle, and Upper Sandstones of Gaspé and New Brunswick.*

On the other hand, Dr. Woodward refers to the discovery of some 300 pteraspidian fishes in the Lower Devonian rocks of Cornwall, while *Phyllolepis*,† *Coccosteus*, and other fish-remains occur in the Upper Devonian strata. It is also to be noted that numerous fishes of the Middle and Upper Devonian system of Russia are specifically identical with those of the Old Red Sandstone of Scotland.‡

The testimony of plant-remains points in a similar direction. The *Parka decipiens* and *Zosterophyllum* of the Arbroath flags, and the grass-like plants of the Glengariff grits of Ireland and East Berwick, indicate plants of an aquatic origin, while *Parka decipiens* (a characteristic fossil of the Arbroath flags and the Kidderminster beds of England) is absent in the Caithness flags. *Psilophyton* and *Arthrostigma* occur in the higher sandstones of Perthshire, but the latter does not range upwards into the flags of Caithness. We also find *Lycopodites*, forms of *Calamites*, *Lepidodendron*, and conifers, abundant in the northern area, but wholly absent in the southern.

The stratigraphical evidence in favour of this view, namely, that the Caithness flags occupy a higher position than the deposits of Midland Scotland, appears to be equally conclusive. If we examine the Upper and Lower divisions of the Old Red Sandstone of Forfarshire we find a strong uncomformity between them, which points to a long-continued period of elevation, and probably an immense denudation, of the lower division of the system. In the Caithness area, on the other hand, the uncon-

* "Geological History of Plants," Dawson, 1888, pp. 279-280.

† Coates and Macnair refer to the discovery of this fish in the Upper Old Red Sandstone of Clashbennie. See "The Old Red Sandstone of Perthshire," *Transactions Perth. Soc. Nat. Science*, vol. i., p. 235.

‡ "Text-book of Geology," Sir A. Geikie, 1882, p. 704.

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formity between the Upper and Lower Old Red Sandstone is scarcely discernible, which undoubtedly shows an almost unbroken sequence in the series of deposits.

The accumulated evidence would appear to indicate that the deposits of Forfarshire chiefly belong to an early period of the Lower Old Red Sandstone, while the upper flagstones of Caithness, and those of the Orkneys, probably represent a long-continued period somewhat later in time.

The Genera of Psilophyton and Lycopodites.—The distinctive characters presented in the genus of *Psilophyton* on the one hand, and *Lycopodites* on the other, have been recognised by geologists for many years. Mr. Carruthers, however, established the genus *Psilophyton Dechenianum*,* in which *Psilophyton* and *Lycopodites* are identified as the same plant. Somewhat later, Mr. Kidston, in adopting Carruthers's view, ranges *Psilophyton robustum* (Dawson) and some additional continental plants under this genus.† With regard to the genus *Psilophyton Dechenianum*, we fail to recognise its *raison d'être*. Mr. Carruthers says of Göppert's *Haliserites Dechenianus*, 1852—"Some of the undoubted plant-remains which have been referred to algæ from the older rocks are only *badly preserved* specimens of more highly organised plants like the *Haliserites* of Devonian age, which is *the leafless branches* of one of the lycopodiaceous plants to which Professor Dawson has given the name *Psilophyton*."‡ That a plant supposed to be of algal origin, showing no rhizomata, circinate vernation, nor fruit—in a word, presenting nothing more than the *branching form* of *Psilophyton*—should be erected into the type of Dawson's plants, possessing rhizomata, stems, branches, and fruit in organic union, seems a rather incongruous idea. Even the case of a prior discovery cannot be advanced in its favour, for Miller's fucoids of 1841, possessing branches *rolled up in a circinate manner*, as in *Psilophyton*, is undoubtedly an earlier discovery. We hope in the following part of our paper to show why this composite name *(P. Dechenianus)* should be dropped, and why the more appropriate names given to these plants by Dawson and Geikie should stand.

In 1841 Hugh Miller figured some fragmentary plants from the

* *Journal of Botany*, 1873.

† "Cat. Brit. Mus. Palæozoic Plants," 1886, p. 232.

‡ *Proc. Geol. Association*, vol. 5, No. 1, 1877, p. 5.

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Old Red Sandstone of Cromarty, which he referred to sea-weeds,* but, in 1849,† and again in 1857, he figured more perfect specimens. The plant whose "slim terminations are usually bent into hooks like the tendrils of the pea" is reproduced in the latter work, while another plant from the flags of Thurso is figured and described as a terrestrial plant, "which in size and general appearance not a little resembles one of our common club-mosses, *Lycopodium clavatum*." "Here, for instance . . . is there a specimen of *Lycopodium clavatum* from one of these Caithness moors that agrees branch for branch, and both in the disposition of the scales and in general outline, with the specimen in the stone."‡ Mr. Salter determined Miller's "terrestrial plant" as *Lycopodites Milleri*, and says that "the leaves are very indistinct, but about one-third of an inch long, lanceolate, and much curved upward to one side. There are some indications of their being set on in spiral lines instead of quincuncially." Some other plants from the Caithness flags he doubtfully referred to *Lepidodendron nothum* (Unger), and rootlets of conifers.§

That the discovery by Sir William Dawson of some very perfect plants in the sandstone of Gaspé and New Brunswick proved an era in the history of the flora of the Devonian period there can be little room for doubt. The discovery of plants possessing rhizomata, stems, branches, and fruit, in a remarkably perfect state of preservation, threw a flood of light upon the somewhat imperfect plant-remains of the Old Red Sandstone of Scotland, and gave an impetus to investigation with regard to these plants which still continues. Dawson named them *Psilophyton*, and also refers to the genus *Lycopodites*.‖ In 1877 Messrs. Jack and Etheridge recognised the genera of *Psilophyton* and *Lycopodites*,¶ while in the following year Sir A. Geikie refers to *Psilophyton* of two kinds, and also to *Lycopodites*.** In 1882 the same author figures as *Psilophyton robustum*†† some plants from the sandstones of

* "Old Red Sandstone," 1841, p. 100.

† "Asterolepis of Stromness," 1849, p. 186.

‡ "Testimony of the Rocks," 1857, pp. 429, 432, 433.

§ *Quarterly Journal Geological Society*, vol. xiv., p. 74, pl. 5, fig. 8.

‖ "Geological Survey of Canada," 1871.

¶ *Quart. Jour. Geol. Soc.*, 1877.

** "The Old Red Sandstone of Western Europe," *op. cit.*, 1878.

†† "Text-book of Geology," 1882, p. 708.

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Gellyburn, Murthly, showing stems, branches, and fruit in organic union.

Leaves of Psilophyton and Lycopodites.—In Dawson's description of *Psilophyton* the following occurs:—"Leaves rudimentary, or short, rigid, and pointed; in barren stems, numerous and spirally arranged; in fertile stems, scattered or absent." . . . "Some of my lately acquired specimens show that the scattered leaflets become *hard*, *spinose*, and *prominent*, confirming my previously expressed opinion that the plant was somewhat *rigid* and *woody*." "The leaves showed a *rigid*, *spine-like* nature by projecting *upward* and *downward into the stone* from flattened stems."* The description of *Psilophyton* (Dawson) by Carruthers, shows a marked discrepancy. He states—"Leaves lanceolate, acute, *densely covering the stem and lower branches, few, or entirely absent in the upper branches*."†

A comparison of the leaves of *Psilophyton* and *Lycopodites* brings out a marked discordance between them. The former are *hard*, *rigid*, *spinose*; in a word, thorn-like. An examination of Dawson's figure‡ shows that the leaves of *Psilophyton* strike outward at right angles to the stem, pointing alternately downward and upward. This is not the character of the leaves of *Lycopodites*, which are lanceolate, set on at an acute upward angle, and apparently imbricate. The latter plant is herbaceous in character, and presents well-defined scales which are wholly absent in *Psilophyton*. Another figure§ indicates that the leaves of *Psilophyton* do not alone cover the stem and lower branches, as Mr. Carruthers supposed, but extend uniformly upward, and into the terminal circinate branches. The best preserved stems should, we think, be taken as the type of the plant, and this being so, Carruthers in describing the leaves of *Psilophyton* is obviously in error.

The assumption made by him that the circinate form of the ultimate branches of *Psilophyton* occurs in *Lycopodites*‖ appears to be equally unfounded. No specimen of *Lycopodites* contains this circinate form of branching. In all cases the terminal

* "Geological Survey of Canada," 1871.

† *Journal of Botany*, 1873.

‡ "Geological Survey of Canada," plate ix., fig. 97.

§ *Ibid.*, plate ix., fig. 101.

‖ *Journal of Botany*, 1873.

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branches present a truncated form, which in specimens covered with leaves become bud-like, as in *Lycopodium*. It is a remarkable fact that, while Carruthers and Kidston admit the correctness of Dawson's genus *Psilophyton princeps* (the latter classing it as a separate genus), a comparison should be made between the leaves of *P. princeps* and *Lycopodites*. We should like to know what value can be attached to a comparison made between the leaves of plants *belonging to different genera?*

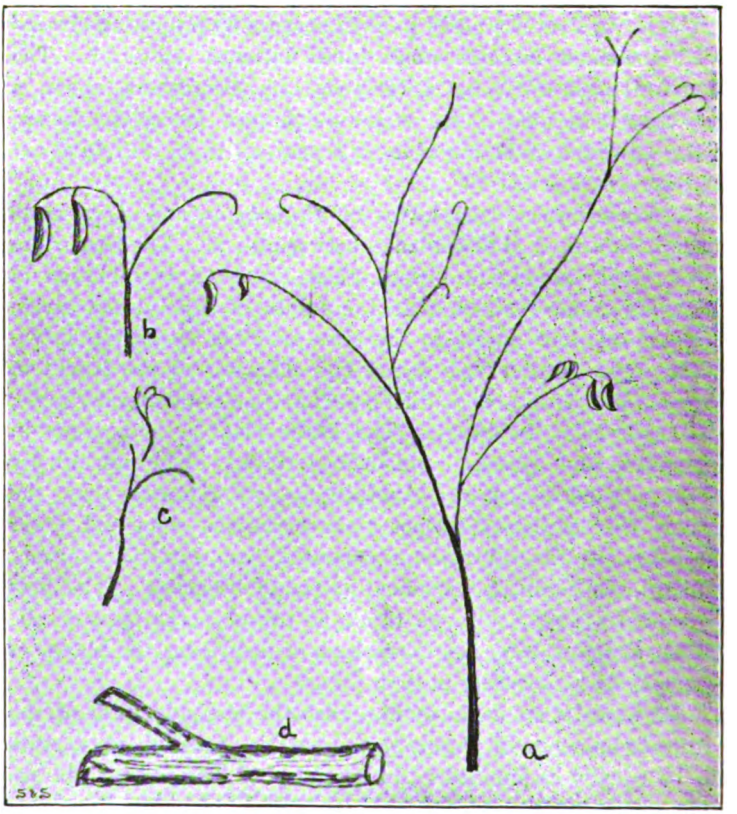

Fig. 1. (*a*, *b*) Restoration of *Psilophyton princeps*. (*c*) Circinate vernation (Caithness). (*d*) Rhizomata (Rosemount).

On the other hand, *Psilophyton robustum*, which Kidston identifies with *Lycopodites*, possesses *no leaves*. Leaves may be

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assumed to have existed, but, as a matter of fact, no leaves occur; for Sir William Dawson says of it—"The habit of growth at once distinguishes this species, as well as the smooth dotted surface, *the absence of distinct leaves*, and the crowded clusters of spore cases."* If no leaves occur in the more perfect plants of the Gaspé sandstones, we may search in vain for evidence of leaves in the decorticated plants of the Scottish Old Red Sandstone. The fact is well known that no leaves occur. A comparison therefore can alone be justifiably made between *Psilophyton robustum*, whose structure is woody, stem and branches devoid of leaves, and fruit consists of clusters of spore cases, and *Lycopodites*, which is of a more herbaceous character, showing leaves lanceolate and imbricated, and whose fruit until recently was unknown.

The Psilophyton Beds of the Old Red Sandstone of Perthshire.—The more recent discovery of the plant-beds of the Old Red Sandstone of Perthshire affords additional evidence in favour of the distinctive characters of *Psilophyton* and *Lycopodites*. From Callander to Logie Almond, the Shochie, Murthly, and Rosemount near Blairgowrie, these upper sandstones for many feet in depth contain a profuse assemblage of stems and branches of *Psilophyton*. If the latter and *Lycopodites* were identical, we should be prepared to find in some of these beds evidence of the fact, but from Callander on the one hand to Rosemount on the other not a trace of *Lycopodites* has been discovered in any of them.

The Fruit of Lycopodites.—In 1891, through the kindness of a friend in Caithness,† we obtained a fertile specimen of *Lycopodites* which is described by Professor Penhallow as follows:—"The specimen is a carbonised fertile stem 8 cm. long, and 6 mm. wide, showing a short branch near the base. The leaves are narrowly lanceolate, acute, and somewhat spreading. The basal articulation of the scales is obscure, but, among these organs, sometimes strictly basal, or again scattered irregularly over the entire remains, are carbonised sporangia 1 mm. in diameter. The indications of the specimen point to a spiral arrangement of the leaves. The whole aspect of the plant is strongly suggestive of *Lycopodium selago*, both in its general form and the way the fruit is produced." The description is—"Stems branching;

* "Geological Survey of Canada," 1871, p. 39.

† Mr. D. Calder, Thurso.

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leaves disposed spirally, narrowly lanceolate, acute, 5 mm. long, 1 mm. broad at the base; sporangia globular, 1 mm. broad."*

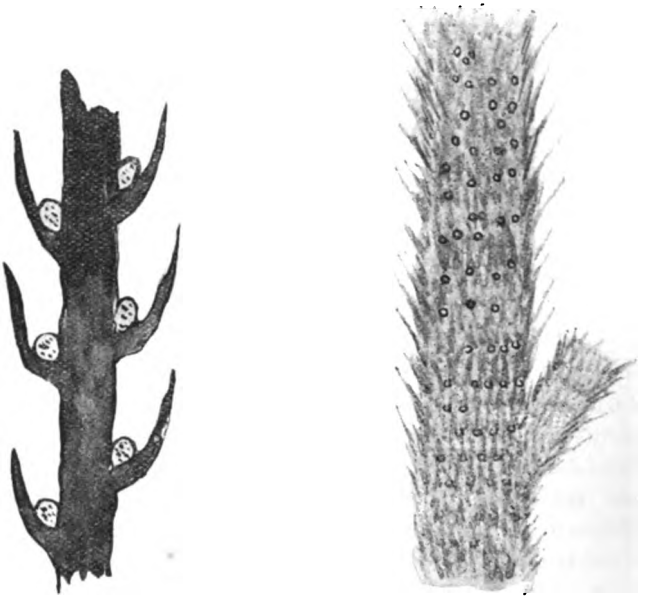

Fig. 2.

(*a*) *Lycopodites Reidii*, showing stem, leaves and sporangia, after Penhallow.
(*b*) *Lycopodites Reidii*, showing sporangia scattered over stem.

Conclusion.—From the evidence adduced, it will be seen that the character of *Psilophyton* is distinctly woody, while that of *Lycopodites* is more herbaceous. The so-called leaves of the former are *hard*, *spinose*, or *thorn-like*, but those of the latter are truly lanceolate. The fruit of *Psilophyton* occurs in terminal spore-cases, while in *Lycopodites* the fruit is *sessile* and *globular*. As these characters constitute well-defined and distinct genera, it follows that *Psilophyton Dechenianum*, being founded upon *the identity of plants generically distinct*, possesses no title to stand, and that Dawson's *Psilophyton* on the one hand, and Salter's *Lycopodites* on the other, should be recognised as the correct determinations of these genera.

* *Canadian Record of Science*, 1892, p. 9.

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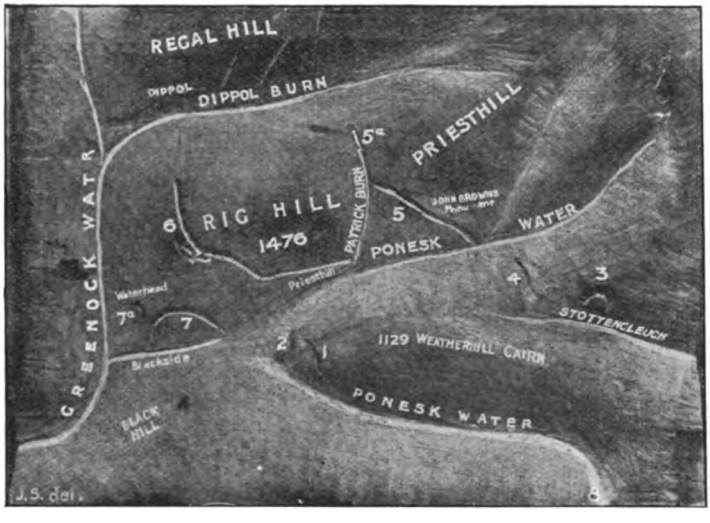
No. XXXII.—Dry River Channels in the Neighbourhood of Muirkirk. By John Smith. With an Illustration.

[Read 10th January, 1895.]

Whilst hunting up archæological remains in the parish of Muirkirk in October, 1894, I stumbled across some curious old Dry River Channels, of which I shall now give a short account.

First.—For a short way in the neighbourhood of Priesthill the Ponesk Water flows west, then with a radius of about two furlongs it wheels round and flows through a deep glen in a south-easterly direction. Towards the south-west side of this bend there are—on the inside of the curve—two projecting promontories of rock, both of which have been cut off to a certain extent by two channels.



Plan of Dry River Channels, Muirkirk.

When on the high ground on the south side of the Ponesk Water I saw the first one—that lowest down the stream—for a time I was fairly deceived by it, believing it to be the ditch or moat of an ancient fort. After an examination I have now not the slightest doubt that the point of land cut off by this old high and dry channel has been used at one time as a fort. It is scarped round the side towards the stream, and right across the

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centre of the ditch or channel there is an entrance roadway, raised 5 feet above the bottom, exactly in the manner we see adopted in connection with many of the existing old forts.

The length of this channel is 321 paces; it curves slightly, and towards its south-east end it is between 20 and 30 feet deep. It appears to be cut entirely out of solid rock, but towards its north-west end it is now partly filled up with peat. Here it widens out somewhat, the remainder being narrow at the bottom with steeply sloping sides. Both ends are high above the present stream, and there is no running water in it. The point of land cut off is 157 paces in length. (No. 1 on plan, p. 331.)

Second.—The next channel, which is a short distance north-west of the first one, lies at a lower level than it, but is considerably shorter and much wider. It also is cut out of the solid rock, and is high and dry above the present stream, cutting off a small point of land. (No. 2 on plan.)

Third.—The old road from Glenbuck to Dippal passes through this channel. It is about a mile from Spireslack, curves considerably, cutting off a hillock of land, and is both deep and wide. (No. 3 on plan.)

Fourth.—The fourth channel cuts across the felstone ridge in the neighbourhood, to the south of Nether Priesthills Cot (now demolished). It makes a long S-shaped bend 136 paces in length, is cut out of solid rock, and is at a great height above the water of the Ponesk Burn, and that of Stottencheuch. (No. 4 on plan.)

Fifth.—The fifth channel is continuous with the little stream which flows past John Brown's Monument. It is 730 paces in length, with a sinuous course. Its north-east end dips slightly towards the Patrick Burn, and the gap at the head of that stream has probably at one time been a continuation of it. There is a ditch along the bottom which requires to be kept clear by the farmer for drainage of the adjoining land. The bottom of this channel is much wider than that of any of those previously described, and it appears to be partly cut out of Boulder-clay. (Nos. 5 and 5*a* on plan.)

Sixth.—This channel commences on the side of the Rig Hill, is of full width *all at once*, and is high above the Dippal Burn opposite the shepherd's house. It cuts across the south-west brow of Rig Hill, and resembles a deep railway cutting; in fact, the shepherd on this hill has already set it down as a ready-made way

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for the long-talked-of Muirkirk and Strathaven railway. It runs a slightly curving and sinuous course of 950 paces, the bottom opening out at one part to 20 and 30 yards. There are some curious hummocks along its south-west side, and it appears to be partly cut out of Boulder-clay. (No. 6 on plan.)

Seventh.—The seventh channel is the finest of the series. It commences wide and deep on the hill-side, and cuts through the same side of Rig Hill as the one previously noted, but considerably lower down. After a course of 1250 paces, it emerges on the flat land to the west of the bend of the Ponesk Water. It appears to be mostly cut out of solid rock, and is at parts 70 to 80 feet deep. At one place it widens out to 20 or 30 yards, and is sinuous in its course, curving towards the right. There is a ditch in it which requires to be kept open by the farmer for the drainage. At one part not far from its north-west end there is a breach in the south-west side where a small burn crosses on the level, leaving a small quantity of débris in it, but this stream can have had nothing to do with the cutting out of the channel. Near its western end there is a short curving dry channel, which at one time may have been continuous with number 7. (Nos. 7 and 7*a* on plan.)

If these channels have been cut during the glacial age—let us suppose during the latter part of it—then they may have been made at a time when the valley of the Greenock Water was choked up with ice, which came down from Middlefield Law and obliged the waters of the district to flow in a south-east direction towards the head of the Ayr Water.

If they are pre-glacial, it is difficult to understand how they escaped being filled up (at least partly) with Boulder-clay. From the nature of the ground and the great height at which they are placed above the present drainage of the district, it is quite out of the question that these channels can be post-glacial.

It is quite possible that the Ponesk Burn at one time flowed into the Greenock Water near Blackside, and the deep channel cut by it across the felstone ridge from the second channel in a south-east direction looks as if it had begun to be formed about the same period as those previously described; in fact it may be classed as one of the series, but the longest and deepest one.

For the photograph of the model from which the illustration has been taken, I am indebted to my friend, Mr. Robert Dunlop of Airdrie.

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No. XXXIII.—Notes on the Ostracoda found in the Lacustrine, or Freshwater, Strata of the Campsie District, which alternate with the Lower Beds of the Carboniferous Marine Limestone Series.

By John Young, LL.D., F.G.S.

[Read 11th April, 1895.]

In the summer of last year, while paying a visit to one of my old favourite localities for Carboniferous fossils, viz., Craigenglen, on the South Hill of Campsie, I again renewed acquaintance with some blocks of a lacustrine limestone which lie scattered about on the hillside, or strewn along the bed of the burn. The position of this limestone is in the Lower Carboniferous marine limestone series of the district, and the blocks seem to have come from some of the mines on the hillside when the clay ironstone was being worked in the earlier part of the present century.

Many years ago, after noticing that this limestone contained numerous examples of the minute shells of Ostracoda, I collected specimens of the weathered rock, crushed them to powder, and washed them, by a process which I described to the Society.* The result was that I was able to collect and mount the four species of Ostracoda which I exhibit this evening. Since then I have obtained a fifth species from the same limestone. These species have been investigated and described by Prof. T. Rupert Jones and Mr. J. W. Kirkby, who found that four out of the five were new to science, and all of these were afterwards named and figured by them.†

At the time I first found these Ostracoda in the Campsie limestone I had not examined the rock in thin transparent sections under the microscope, but several of the specimens collected on my recent visit to Craigenglen I have since sectioned and examined. In sectioning some portions of the limestone, which showed externally to the naked eye a minute brecciated structure, I was very much interested to find that it frequently had single valves of the shells of the Ostracoda collected into neat little nest-like groups containing from two to nine or more specimens in each. They were often closely assorted in size and form, one within and above the other, like piles of saucers, in little crevices

*_Transactions_, vol. ii., 1866, p. 155.

† See _Carbonia_ in List of Carboniferous Ostracoda, _Transactions_, vol. ix., 1893, p. 311.

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between the fragments of the breccia, and were surrounded with a matrix of calcite, which, subsequently infiltered, had cemented the fragments of the breccia together. The shells, it may be stated, are generally well preserved, their thin and delicate valves being neither crushed nor distorted. In looking over the sections, one is struck with interest at the great regularity in this arrangement of the valves, both in relation to size and shape. This peculiar feature distinguishes this variety of the limestone from all other parts of the rock in which the Ostracoda exist, and from which the brecciated structure is absent.

The occurrence of these nest-like groups has suggested to my mind as an explanation that the dead shells were drifted by gentle currents of water from portions of the lake-bottom to other tracts where the sediments had been for a time laid bare through a retreat of the waters. These sediments, under the drying power of the sun, would be minutely cracked and fissured, as seen along many lake-shores at the present day; and into such openings the valves of the Ostracoda would be swept by the returning waters, the currents having probably some assorting and selecting power which gave them, according to size and shape, the neat arrangement in which they now lie. They were then preserved from crushing or distortion by the after-infiltration of a soluble calcite into the fissures.

Since I first discovered this nest-like arrangement of the Ostracoda which I have now endeavoured to describe, in the brecciated limestone at Campsie, I have looked for a similar occurrence in other lacustrine limestones where shells of the family abound, but have not been able to detect it in any of them. This seems to indicate that before such an arrangement of the shell-valves could have taken place some such conditions as those I have supposed above must have existed, producing (1) the fissuring of the stratum into a brecciated rock, and (2) the introduction of the shells of the Ostracoda into the fissures through the action of a current of water.

In the Campsie district there are at least three or four horizons in which limestone strata of freshwater origin occur, all containing the remains of Ostracoda, which are characteristic of lacustrine conditions, although they lie amongst and alternate with marine strata belonging to the Lower Carboniferous series. The shells lie

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scattered about in the rock, either in single valves, or with the valves united as in life; and only in the brecciated rock found in and near Craigenglen, which appears to be local in its occurrence, have I found the peculiar and interesting arrangement noted in the foregoing remarks. It is further worthy of note, that as the shells of the Ostracoda in the brecciated limestone are very seldom found with their valves united, it is probable they were longer drifted about by currents of water than those found in the non-brecciated strata.

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No. XXXIV.—The Coast-Line of Berwickshire from Eyemouth to Marshall Meadows Bay. By James S. M'Lennan.

[Read 9th January, 1895.]

Having visited several portions of the coast-line of East Berwickshire in company with Dr. Macvie of Chirnside, and Mr. Elder of Jardinefield—who are intelligently acquainted with the district—I thought it might interest members to whom the locality is new were I to give a short account of some of the interesting things I had seen during our excursion.

The geological associations connected with the coast-line of Berwickshire, which had their origin in the earlier days of the science, and resulted in furnishing the means for solving some of its hitherto unexplained problems, give to a section of this sea-shore a high and enduring interest. It was among the highly contorted Silurian strata which form the bold headlands lying to the east of Cockburnspath that Hutton gathered part of the proofs and illustrations of his famous work, "The Theory of the Earth, 1795," wherein he shows that the various changes undergone by the earth's crust in the past were similar to those happening in recent times; that the grits and shales, at first laid down horizontally on the sea-bottom, had been convoluted and placed on end; and that their exposed edges had been worn down by the action of waves, which had placed upon them a series of gently inclined sandstones and conglomerates. Here, also, Sir James Hall of Dunglas, well known for his geological papers in the *Transactions of the Royal Society of Edinburgh*, made those observations on the effects of lateral pressure in crumpling and contorting large masses of stratified rocks which he afterwards demonstrated by experiment, and which have thrown much light on the peculiar form of stratification presented by Silurian rocks in many localities.

The picturesque village of Burnmouth, which we first visited, is situated along a curve of the coast-line some three miles south of Eyemouth, at the base of the cliffs, and a few feet distant from high-water mark. From the North British Railway station on the level ground above the precipitous cliff, a road leads down a steep gorge to the village below. This glen has been hollowed out through highly convoluted Silurian strata, which are crossed

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by several felstone dykes. The bends and contortions of these rocks are well seen, especially on the northern side of the declivity, where a thick brown-coloured dyke of felstone runs across a synclinal trough of the strata, which on the south-west side are thrown into a vertical position. The shore at the bottom is covered with long parallel ridges of rock running almost north-east and south-west. These consist of Lower Carboniferous sandstones and shales lying nearly vertical, and they owe their present situation to being faulted down against the older rocks.

Turning now towards the north and passing Partonhall we find that the coast-line rises in precipitous cliffs, with great masses of fallen rock flanking their bases, covering the narrow shore, and even protruding into the sea. These Silurian grits and shales, which dip N.-W., are in many places traversed by dykes of felstone running parallel with the strike of the strata whose softer materials have been denuded away, leaving the dykes standing out in isolated crags and stacks. One of these, known as "The Breeches Rock," has been excavated right through by the action of the waves, and when seen from some positions presents the aspect of a pair of gigantic human legs. A similar mass, known as "The Gull Rock," rises in prominent relief a little further north, and forms a great resort for the sea-fowl. Beyond it the Silurian rocks present some fine examples of highly twisted, folded, and shattered strata, the arches and troughs being occasionally complicated by small displacements.

Still farther to the north the strata become more crumpled, with larger and more regularly-defined foldings. At Fan Cove Head a good example of a trough is seen, and from this cape to the little bay of Harker Haven the lofty cliffs present two anticlinal and two synclinal axes. Beyond these, at Bleak Heigh, the precipices rise to the height of 337 feet above sea-level. On the base of this headland a felstone dyke runs through the Silurian grits and shales; and at Scout Cove there is a greenstone dyke, the rock of which, in weathering, has broken away in spherical masses, leaving a long gloomy cavern. Northward from this cove the strata still keep the N.-W. dip, and exhibit many smaller twistings and foldings. Near Eyemouth these flexures become more numerous until the rocks disappear beneath the waters of the bay, where they are supposed to be cut off by a

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fault. On the western side of this bay a mass of ash and conglomerate of Old Red Sandstone age extends for nearly a mile, beyond which the Silurian rocks again appear.

The great elevated tract of Silurian strata, forming what is known as the Southern Highlands of Scotland, has an anticlinal axis, which, running south of the town of Moffat, extends from the German Ocean on the east to the Atlantic Ocean on the west. The rocks on its north-west side, which are greatly crumpled and folded, dip N.-W.; and where exposed in the hills in this direction the strata are seen to belong to the upper portion of the system, as in the Pentlands, at Lesmahagow, and in the valley of the Girvan. On the southern side of this axis the same holds true as is displayed in the upper Silurian strata of Kirkcudbright and Cumberland. Thus it appears that the rocks at the centre of the axis are lower and older than those met with on the outer edges of this great Silurian tract.

This central axis has not been distinctly traced so far to the east as the German Ocean. Crossing the Lammermuirs to Gifford in East Lothian the strata present a N.-W. dip, while near Fast Castle, on the sea-shore, the inclination is to the S.-E.; but the coast section between Eyemouth and Burnmouth, as already mentioned, shows a N.-W. dip. Perhaps the axis at Fast Castle is a minor one, and the great fold may lie more to the south-east, near the town of Berwick.

Such great foldings of strata are by some geologists supposed to have taken place from the shrinking and contraction of the earth's crust, caused by the loss of heat from radiation, and that this decrease in temperature induced those twists and convolutions of the strata during the slow sinking of a portion. While this was going on the rocks underneath were necessarily forced to occupy less space under great pressure.

"The depression," says Dr. James Geikie in his "Fragments of Earth Lore," "of a few hundred feet at the surface implies a considerably greater depression at the depth of several thousand feet from the surface, and it is at great depths, therefore, that the most violent foldings must have taken place. It follows that if we now get a highly contorted structure, covering wide areas at the surface, we suspect that a very considerable denudation has taken place, and that an incalculable lapse of time was

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necessary to allow of the gradual wearing away by rain, frost, and running water of the great thickness of rock under which the Silurian strata was crumpled."

Another theory accounting for the formation of these plications of the strata has been put forward by Mr. T. Mellard Reade, F.G.S., in his "Origin of Mountain Ranges." "These foldings," he asserts, "are caused, not by a decrease but by an increase of temperature, which by its consequent expansion has elevated and contorted the strata of the region underneath which this change of temperature has occurred." He contends that the lines of fracture through which, at later periods, masses of molten matter, now known as dykes, were upraised, were caused by the shrinking of the already elevated strata from the loss of their caloric.

A third theory, which finds favour amongst American geologists, assigns such flexures of the strata to the effect produced on the then thinner crust of the earth by the enormous sedimentation, "which weighed down the surface and caused great masses of sediment to come within the influence of the heated interior nucleus. Thus extensive metamorphism took place and, at length, the tension becoming too great to be any longer maintained, a second collapse occurred, crumpling and disturbing the crust, and throwing up mountain masses, many of which still remain of considerable elevation, although they have undergone denudation throughout all the succeeding geological periods."

The Lower Silurian rocks of Eastern Berwickshire are found on the surface of the area occupied by the Lammermuir Hills, also on the hilly ground known as Lamberton Moor which extends from Eyemouth nearly to the town of Berwick, and stretch for 1½ mile along the shore between Eyemouth and Coldingham. They are very much alike in mineralogical character, being composed of shales and sandstones or grits, which vary in thickness from an inch to several feet. The sandstones are commonly dull yellow or bluish-green, and in texture they range from fine- to coarse-grained. There is also a pebbly conglomerate. The shales and sandstones appear to have been formed from the mud and fine sand gathered into calm reaches of the sea, while the grits and pebbles were laid down near the shore as gravel by the streams which drained the land-surfaces.

These Silurian rocks are generally supposed to lie immediately

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beneath the Silurian strata of South Ayrshire, but unlike them are very barren in fossils. Sir Archibald Geikie found a well-preserved specimen of *Graptolithus priodon* in a shale exposed near Siccar Point.

On the western side of Eyemouth Bay a series of sandstones and fine conglomerates extends south-west as far as Billy Mire Burn, in a rectangular area, averaging 5 miles by 3 (with the exception of the Silurian patch on the Coldingham shore already mentioned). From their contained fossils these rocks have been assigned to the Lower Old Red Sandstone. In some of the shales exposed on the banks of the Ale Water, near Ayton, fragmentary remains of linear or grass-like plants have been found, and at Auchengray Burn a large portion of a *Pterygotus* was discovered by the officers of the Geological Survey. The unconformity of these sandstones with the Silurians they overlie is very distinctly marked, and Mr. Mellard Reade in the *Geological Magazine* for 1896 says—"So perfectly are the two formations cemented together that it is possible to get hand-specimens of the unconformity." The conglomerates they enclose are in many places of a highly felspathic character, received from the eruptions of volcanic ash poured over them when they formed a rough sea-bottom.

Below the fort which forms the north-west point of Eyemouth Bay this feature is well seen, the rock being there of a mottled light-red colour, and composed of angular fragments of felspathic and porphyritic rocks similar in appearance to a true volcanic ash. In some places the fragments become fewer, and there the rock looks like a felstone; though it must not be mistaken for the brownish felstones so frequently found among Silurian strata. The former have been poured over the ocean bed, while the latter have been forced up among rocks already formed.

Overlying the Lower Old Red Sandstone rocks on the west of Eyemouth Bay there is a small eminence called "The Fort," which is composed of strata belonging to the upper portion of the formation. It is made up of conglomerates mostly derived from the underlying felspathic rocks already referred to, on which they rest unconformably. Some are remarkably hard and compact, and have been used for building purposes. Dr. Milne Home mentioned in 1835 that the sea-wall of Eyemouth harbour had been built of these

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conglomerates, and that it had needed no repairs for the preceding fifty years. Recently this harbour has been largely extended and improved, and I doubt if the old sea-wall can now be seen.

Another outlier of the same rock is found overhanging the top of a cliff near Hawk's Heugh, where the precipices are 300 feet above sea-level. "In Burnmouth Glen, where its northern side forms a steep bank, between the bend of the Partonhall road and the space immediately above the high-water mark, lies a small patch of what is probably a conglomerate of the same age as that already described."*

About half a mile south of Burnmouth another of these outliers is found on the side of Chester Hill at a height of 560 feet above the sea. It is some 70 feet in thickness and covers nearly 600 square yards, and it lies unconformably on the Lower Silurians of the district. In the railway cutting near Pemberton Fishery another fragment of the same is met with. Again, on the sides of the Silurian heights between Marshall Meadows and the "Steps of Grace," the largest of these patches occurs. The main mass of the Upper Old Red Sandstone extends in the form of a rude triangle wanting its apex—with a base 10 miles in length and a height of some 2 miles. But its best exposure in the district is found on the banks of the Whitadder Burn near Cockburn Mill, where a red marly conglomerate has yielded fragments of ganoid scales, and Mr. Stevenson found a specimen of *Cyclopteris Hibernicus*, while at Harlaw quarry, near Chirnside, plates and scales of *Bothriolepis ornatus* have been discovered. From the detached condition in which the Upper Old Red Sandstone is found, we may infer that this deposit must at one time have covered the whole district, and that it has been removed by immense and long-continued denudation.

From Burnmouth along the coast-line as far as Berwick there occurs a narrow strip composed of Carboniferous rocks faulted down, the contents of which are well exposed in the splendid cliffs bounding this portion of the shore. At Burnmouth, the calciferous white and grey sandstones and shales are met with, as already mentioned, lying in nearly a vertical position, the harder sandstones forming long parallel ridges, while the softer beds have been scooped out so that they hold pools of sea-water, with stones and sea-weeds. These

* Memoir of the Geological Survey.

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strata are well seen on the steep bank overhanging the harbour, and also on the beach at the pier. After passing the village of Ross, while walking over their exposed vertical edges, there are sudden changes in the colours of the various layers—red, green, grey, and lilac; the same colours occurring several times in the thickness of a few feet. The grey marly shales are said to contain fragmentary remains of plants along with some fish scales. Above these a thin seam of impure limestone in a vertical position is seen ascending the cliff at the west end of the village of Ross, where from weathering its fossil contents can be noted. From this limestone a continuous ascending section is exposed along the shore and up the cliffs, consisting of green, grey, and reddish sandstones, or marly shales and cementstones, with bands of grey, reddish, and white sandstones, till we reach the base of the Carboniferous limestone series at Hilton Bay.

In one place, on the side of a vertical mass of reddish sandstone, there was seen a dark circular ring, some 3 inches broad by 18 inches in diameter, with a rounded dark spot in the centre, and probably caused by some organic matter which had spread outwards from the centre. In another part there was an exposure of curiously contorted shales of variegated colour, reminding us of a similar one on the shore at Ardniel Bay, West Kilbride, which is well described by Mr. Dugald Bell, F.G.S., in the *Transactions.** A little further south our attention was arrested by "The Maiden Stone," a sea-stack about 50 feet high, 40 feet long, and 4 feet thick, very much shattered at the top, and of similar character to the cliffs. It owes its existence as a stack to having its base composed of harder material than that of the mass which once surrounded it.

I may mention here that other exposures of the calciferous sandstone series can be seen on the banks of the Whitadder at Edrom and Chirnside, and are said to belong to a lower horizon than those of the Burnmouth shore. They contain plant-remains, also *Cypris*, *Anthracomya*, and fragments of *Rhizodus Hibberti*.

At Hilton Bay, to the south, there is a band of limestone, regarded as the base of the limestone group; also a thin layer of coralline limestone, which is thus referred to by Sir Archibald Geikie:—"In Hilton Bay the strata are well shown both on the

* *Transactions*, vol. vii., part 2, p. 348.

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beach and on a prominent cliff which here protrudes its wasted rocks into the ocean. We see how the fault by which these Carboniferous deposits have been depressed has not only tilted them on end, but actually reversed their inclination, so that the upper surface of one bed rests on the under surface of its neighbour. That this is the true arrangement cannot be better shown than by the band of coralline limestone which runs out as a reef in the centre of the bay. For if this bed be examined it will be found that the branches of coral are all lying with their roots upwards, a position which is only explicable by admitting that the bed has been turned over. East of this only a few yards the strata are quite vertical, and in the outstanding cliff alluded to they right themselves with remarkable rapidity, so much so that at its seaward end the inclination is no more than about 8° or 10°."

This band of Carboniferous limestone is found running along the face of the cliffs from Hilton Bay as far south as St. John's Haven, and between these places the cliffs range from 100 feet to 150 feet in height. About ¾-mile south of Hilton Bay the red sandstones assume a horizontal position. At Lamberton the limestone is from 1 foot to 3 feet in thickness, dull reddish in colour, and contains abundance of characteristic fossils.

Below it is a seam of coal, and a few feet lower another is met with. These have been worked both by pits and "ingaun ees" at Megs Dubs and at Marshall Meadows, but not being very profitable their working ceased nearly forty years ago. When it was last wrought the face consisted of 1 foot 8 inches of "rough coal," 2 feet of very fine fire-clay, and 1 foot 4 inches of "hard coal." Its roof was 6 feet of fire-clay, which made it very expensive to work, and this, combined with the inferior quality of the coal produced, led to the operations being suspended. A little more to the south a small indentation in the coast-line, called Marshall Meadows Bay, is surrounded by splendid cliffs 150 feet high, which show the various layers of sandstone, shale, coal, and limestone in fine form and of lengthened extent. From this bay, which has a narrow sandy beach on which the fishermen dry some of their salmon nets, there is a tunnel leading by a steep gradient for nearly 100 yards up to the top of the cliffs close to the fisherman's cottage, and quite near the farmhouse of Marshall Meadows.

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As showing the precipitous nature of the coast-line traversed—of which I have attempted to give you a brief outline—I may mention that in the 5 miles under review there are only two places where the top of the cliffs can be reached—one by a steep grass-covered slope at Hilton Bay, and the other at Marshall Meadows Bay by means of the tunnel aforesaid.

Among the boulders lying on this shore there are many black-coloured ones of a dark greenstone, very common in the Merse, and also the red porphyritic ones numerous at Hilton Bay, which have been brought from a patch of porphyrite near Mordington, 1½ mile to the west of where they are now found.

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No. XXXV.—On the High-level Shelly Deposits, and their Bearing on the Question of Submergence; with Special Reference to the Recent (Third) Edition of Dr. James Geikie's "Great Ice Age." By Dugald Bell, F.G.S.

[Read 9th May, 1895.]

*Abstract.

Dr. Geikie had intimated that he no longer believed in a "great submergence" of about 1400 feet during the Glacial period, which had been inferred from such high-level shelly "drifts" as those of Moel Tryfaen, in Wales. These, he admitted, were most probably transported to their present position by an ice-sheet. He still, however, believed in a submergence of from 500 to 600 feet, the evidence for which rests on one or two instances of high-level shelly clay in the west and north of Scotland. Indeed, it may be said to rest on only one instance; for the Aberdeenshire "beds," it was tolerably clear, could not be accepted as proofs of submergence; and another and, till lately, leading instance was in this edition "conspicuous by its absence." Chapelhall, near Airdrie, which had figured so largely in connection with this subject for forty years, and on which great stress was formerly laid by Dr. Geikie, is now entirely omitted from the "Great Ice Age" without a word of explanation! It seemed unusual to allow one's favourite facts thus to sink out of sight without some brief *In Memoriam* being inserted where they once figured so largely.

But Chapelhall being thus summarily discarded, Clava, near Inverness, which had become known since the previous edition, might be said to be the single instance on which Dr. Geikie had to rest his proof of a submergence of about 500 feet. It was, so to speak, the "a'e button" which had to bear a great "responsibility." Accordingly, in the new edition much is made of Clava. A minority of the Committee appointed by the British Association to investigate these high-level beds were inclined to think that the shelly deposit there may have been transported by ice to an elevation of 500 feet, just as that of Moel Tryfaen had been to an elevation of 1400 feet. But Dr. Geikie will have none of this. Moel Tryfaen he admits, but Clava, he thinks, would be a "freak" of the ice, and

*The substance of this paper appeared more fully in the *Geological Magazine* for July, August, and September, 1895. An abstract, therefore, is only now given.

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a "remarkable performance." The argument that if there had been a submergence to the extent of 500 feet, we should find traces of it in innumerable localities up to that level—though formerly it appeared to himself unanswerable (second edition, p. 390), Dr. Geikie now dismisses by saying "it does not necessarily follow." The submergence, he supposes, may have been sudden and of short duration; or marine life may have been scanty; or all traces of it may have been removed by a subsequent glaciation. With all deference, these suppositions appear to be greater "freaks" and more "remarkable performances" than any imagined on the other side; and they include not only the ice but also the sea and the solid land. The last conjecture, which is the most plausible, has been dealt with elsewhere,* and can be refuted in Dr. Geikie's own words ("Great Ice Age," 3rd ed., pp. 108, 109, 112, &c.).

With regard to Clava, it can be maintained that there is nothing in the deposit which necessitates recourse to a submergence; but much, in addition to the absence of traces of it at a similar level elsewhere, that is inconsistent with it. Dr. Geikie spoke of the shelly clay having been "dragged forward underneath an ice-sheet" for a distance of 10 or 12 miles; but he can hardly insist on this particular mode of transport, seeing he informs us that "stones or boulders, once imbedded in the ice, might travel for hundreds of miles without suffering abrasion" (p. 204). The apparent extent of the deposit—which appeared to be Dr. Geikie's principal, if not sole, difficulty—even if granted as proved, did not seem to be an insuperable objection to the ice-theory. Numerous instances were known in which large masses of clay and sand, and thin slabs of chalk, &c., had been transported uninjured by the ice.

But whatever weight attached to this objection depended entirely upon the assumption that the deposit had all been transported by the ice at once, or *en masse*, which, to use Dr. Geikie's words, "does not necessarily follow." It may have been transported very gradually, and accumulated in an extra-glacial lake, formed at this part by the ice-sheet passing across a bend in that range of hills along whose base its course lay. An examination of the locality showed the extreme probability of this suggestion, which was submitted as at least preferable to sudden and transient submergences

* *Transactions*, vol. ix., pp. 109-110.

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of 500 feet—seas with scarcely any marine life—and glaciers that cleared away all traces of a former sea-bed, over only part of which they could have passed. It not merely removed the objection referred to, but also accounted in some degree for several features of the deposit which, on the theory of a submergence, seemed inexplicable—such as the absence of all traces of currents in the clay, yet the worn and rounded stones imbedded in the heart of it; the sharp line of distinction between it and the other parts of the section; its wide difference from these in composition, &c.

Reference was then made to the frequent elevations and depressions which Dr. Geikie still favoured during the Glacial period; their want of harmony with what had been observed in other parts of the northern hemisphere; their improbability in themselves, and especially in the repeated conjunction, according to his scheme, of submergence with severe conditions of climate ("Great Ice Age," 3rd ed., pp. 312-313, 324-325, &c.). So far as could be seen, submergence, by diminishing the extent of high land and more freely admitting the ocean-currents, must have been favourable to milder climatal conditions, as Lord Kelvin, in his paper on *"Geological Climate," has shown.

Mr. Bell concluded by expressing his high respect for Dr. Geikie, though obliged on these points to differ from him.

* *Transactions*, vol. v., p. 245.

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No. XXXVI.—On the Occurrence of Pumice Pebbles in the Raised-beaches of Ayrshire. By John Smith.

[Read 7th May, 1896.]

About two years ago I began to find Pumice Pebbles in the 25-feet Raised-beach at Ardeer in the parish of Stevenston. A short time afterwards I got them from the Raised-beaches near the mouth of the Bann river in the North of Ireland. After my return home I thought of examining the 40-feet Raised-beach of Shewalton Moor, near Irvine, and found the pebbles there to be quite common. For more than twenty years I must have seen these pebbles scores of times, both at Shewalton and Ardeer, but always failed to "discover" them. So much for "eyes and no eyes."

I sent specimens of the pebbles to Professors Hull and Forster-Heddle; to the Jermyn Street Museum, London; to Mr. Goodchild of the Science and Art Museum, Edinburgh; to Mr. William Gray of Belfast; to Mr. James Bennie of the Geological Survey, Edinburgh; and I also shewed them to Mr. John Young, LL.D., F.G.S., of the Hunterian Museum, Glasgow.

Professor Hull wrote—"I cannot say where they [the pumice pebbles] came from, but in a volcanic country such as Ayrshire it is quite conceivable that they might be derived from some lava-flow, either visible or concealed by drift. Their occurrence in the North of Ireland would be in accordance with the well-known trend of the glacial striæ—W.-S.-W. Supposing the solid rock is in the South of Scotland, the pebbles may be derived either from drift pebbles or directly from the rock itself. I regret I cannot say anything more to the point than the above."

Professor Heddle, in writing me about the first pebble I sent him, said—"The rock is unquestionably pumice, with minute crystals of sanadine. Its colour is new to me, and is not due to stain in bog-water. There is certainly no volcano in Britain so recent as to have supplied this, nor in Faröe. Their occurrence on the beaches may help to indicate the age of these beaches; and if none are found on the intermediate slopes, it goes far to prove that the elevation had been a somewhat rapid process. As to their birthplace, I should guess Iceland."

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The Jermyn Street Museum authorities could say nothing about them; they had not seen anything similar.

Mr. Goodchild remarked—"They have a remarkably *fresh* appearance. I don't know any source whence they may have come; but pumice once in any ocean surface-current might drift to very considerable distances, and would be just as liable to reach our shores in 40-feet-beach times as at any other. I confess that the undecomposed character of the rock in general, and especially the glassy lining of the vesicles, would have led me to assign to them an origin more recent."

Mr. Gray of Belfast, said—"We do find on our coast specimens such as you sent me. We have nothing of the kind *in situ* in the North of Ireland, or to my knowledge anywhere in Ireland. What we get on the north coast and about the sand dunes is larger blocks, and composed of more open material than yours, but such fragments like yours are occasionally found. I have hitherto considered that the material was washed ashore, and may be of volcanic origin from America, carried to our locality by the Gulf Stream."

I may here just remark that I also got much larger and also much opener bits than the one sent to Mr. Gray.

Mr. Bennie showed the pumice I sent him to several members of the Survey, but they knew of no rock like it. He also showed it to Mr. J. A. Johnstone, who informed him that he had a piece like it from the Scuir of Eigg.*

This is the only information as to the occurrence *in situ* of rock like the Raised-beach pumice pebbles that I have been able to obtain.

Mr. Bennie also informs me that when the Kingston Dock at Windmillcroft, Glasgow, was being dug out he found a "piece of scoria," about an inch in diameter, similar to the specimens I have been finding in the Ayrshire Raised-beaches. This was about the year 1865. This pebble Mr. Bennie still has, and he says it is of a lighter red than the one I sent him, but I have other specimens which must be much of the same shade as Mr. Bennie's.

Dr. Young, F.G.S., had not seen any pumice similar to that of these Raised-beach pebbles.

* This specimen has unfortunately been lost, so that a comparison cannot now be made.

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I prepared transparent sections of the pumice from the three localities where I found it, and sent them to Dr. Heddle, asking him at the same time to furnish me with some notes on them, and I have since received the following, for which I am much indebted to him:—

"Report on three Microscopic Sections of Pumice, from the Shewalton 40-feet Raised-beach, the Ardeer 25-feet Raised-beach, and the Raised-beaches near the mouth of the River Bann, Ireland. By M. Forster-Heddle, F.R.S.E., &c.

"The structure of the three sections of pumice is very similar. At first sight it appears as a system of vacuous spaces of two forms—the one with rounded outlines, the other angular and rough. These are set, as it were, in an isotropic magma of a yellowish-brown tint. This magma, at the margins of the vacuous spaces, has a somewhat net-work appearance, possibly from some compression at their margins. Closer observation shows that the rounded vacuous spaces have been filled with a glass very similar to that of the magma, but so much more brittle that it has for the most part broken away during the process of grinding. The glass which has filled these rounded spaces is paler in colour than that of the magma. Like it, however, it is sprinkled with a dark-brown dust. The magma or glassy paste is largely made up of rounded particles somewhat more opaque than the rest of the glass. These particles are thickly studded with the brown dust; this is not so absolutely isotropic as the glass itself, and the interstitial glass is profusely sprinkled with minute air-bubbles in clusters.

"Crystalline olivine is present in the Ardeer section in large ill-defined plates; in the river Bann section in single crystals, and in contact-twins, which with the analyzer show zonation tints—yellow and violet; in that from Irvine it is less well-defined, as is indeed the structure as a whole. It might be possible to recognise this specimen from the others, but not the others from each other. In this last slide the air-bubbles cluster in such quantities as to resemble bunches of grapes (African) or little globules of brown pitch.

"Though—from the substance within them having broken away—no concretionary structure can be found in the rounded spaces first alluded to, still the distortion of the air-bubbles which

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surround them proves some structural change, though it may merely be the separation of one glass from another.

"The striking feature is the large amount of remaining included air, which seems to give the lightness to the rock even more than its looseness of structure. This looseness seems unquestionably to be due to the escape of occluded gaseous matter.

"The collecting of a quantity of the rock, and after analysis, might be fruitful of information."

Pumice pebbles occur in the 25- and 40-feet Raised-beach beds of Ayrshire, and in those near the mouth of the river Bann in the north of Ireland, and, so far as I have yet observed, always near the top of these beds. I have collected, perhaps, over a hundred specimens, and found them to be much more common in the 40-feet than in the 25-feet beach. They are, as a rule, very well water-worn, but some of them have suffered slightly from weathering.

In colour they are pale reddish-brown, and dark brown. When broken with the hammer the fractured surfaces are remarkably fresh-looking, and the vesicles are seen to be elongated in the line of flow, but nothing like to the same extent as they are in "painters' pumice." Some are minutely vesicular, others much more open in texture. Some specimens have an occasional sanadine crystal here and there in the larger gas-spaces, and numerous microscopic crystals of olivine are dispersed through the glassy magma. They all float in water.

As to where these pebbles came from, or to what geological formation the pumice belongs, nothing perfectly definite is as yet known. From what Mr. Bennie says, Mr. Johnstone's specimen from the Scuir of Eigg may be a fragment of the same rock, and, if so, this would fix the pumice as perhaps of Tertiary age.

I have as yet seen no specimens like them on the present Ayrshire shore, and even supposing some were to be got there, they might just be specimens carried down the Irvine Water from the Shewalton Raised-beach, which at one part is being rapidly carved away by the river. Even the pebbles in the 25-feet beach may have been derived from the 40-feet beach, but, whether or not, a large flotilla of pumice certainly came to the Ayrshire coast during the 40-feet Raised-beach period.

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My correspondents have scarcely left me any occasion to make a suggestion as to where this Ayrshire pumice may have come from, but it is well known that voyagers have often sailed for days through floating pumice which had been thrown out by submarine volcanoes; and, as this appears to be the only vacant theory left, merely by the way of filling it up I make the suggestion that the pumice of the Ayrshire Raised-beaches may have come from some slumbering submarine volcano situated somewhere to the north or north-west of Ireland.

I have been conducting some experiments as to the floating powers of these pumice pebbles, and I find that those under an inch in diameter will sink in fresh water in six hours, while specimens about three inches in diameter will float for twenty days before sinking. When they were originally fresh, their power of flotation may have probably been somewhat greater.

Note.—Since the above paper was in print Mr. James Neilson has drawn my attention to the following passage in "Report on the Long Island (Outer Hebrides), by W. Macgillivray," in *Prize Essays and Transactions of the Highland Society of Scotland*, vol. viii. (new series vol. vii.), 1831, page 270:—"Several species of seeds from the West Indias, and the *Spirula peronii*, and *Ianthina communis*, which are natives of tropical seas, are frequently found on the beaches. These may be supposed to be carried across the Atlantic by the Gulf Stream. Pumice slags and saturbrand are also occasionally met with on the shores."

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PROCEEDINGS FOR SESSION 1894-95.

(37TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 18TH OCTOBER, 1894.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

A resolution by the Council that students attending geological classes in Glasgow should be eligible for admission as Associates of the Society, at a very small subscription, was unanimously approved.

Mr. W. J. MILLAR, C.E., exhibited specimens of Columnar Sandstone from Kilchattan, Bute, and gave some particulars regarding its occurrence and distribution. An interesting discussion as to the cause of the formation of columnar and prismatic structure in sandstone and other rocks was taken part in by Messrs. James Thomson, F.G.S., Sommerville, Neilson, White, and other members, the general opinion being expressed that in the present and other instances it arose from the action of heated vapours at a time when the strata affected were deeply overlaid by other, presumably igneous, rocks which had since been entirely denuded away. There was a probability that rocks similar to those which had overlain them still underlay the Kilchattan columnar sandstones.

Mr. MILLAR also exhibited a series of North of Ireland Limestone Fossils, many of the typical species being in fine preservation.

The HONORARY SECRETARY (Mr. Murdoch) exhibited several small Boulders which he had picked from the Boulder-clay presently being cut into for a sewer at the point of intersection of Bath and Wellington Streets. One, of felstone, was beautifully striated by ice-action, and two others, of quartzite, had probably been transported by ice from the parent rock considerably to the north-west of Glasgow.

Mr. JAMES ANDERSON read a paper, entitled "Evidences of the Most Recent Glaciers in the Firth of Clyde District." [See page 198.] On a carefully-coloured Ordnance map of the Clyde basin the author pointed out the position of the glaciers he had described at the time of their latest development.

A discussion, which showed more or less agreement by the members with the views expressed in the paper, followed.

The HONORARY SECRETARY (Mr. Murdoch) read a portion of his Report as delegate to the present year's Meeting of the British Association which was

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held at Oxford. He stated that amongst various other Scottish papers and reports, the committee appointed to investigate High-level Shell-beds had reported upon their work in regard to the high-level shell-bed at Chapelhall, Airdrie, to the effect that when the well, where the shell-bearing clay was said to have been originally found, was opened and examined, neither shell-bearing clay nor arctic shells were got, nor had any traces of them been met with in bores put down through the blue Till outside the well. Several of the speakers at the sectional meeting expressed themselves as not satisfied with the result of these investigations at Chapelhall, and thought that further steps should be taken to have any possible doubt on the subject altogether removed.

Messrs. James Thomson, F.G.S., Sommerville, Neilson, and other members who took part in a subsequent discussion agreed with the feeling expressed at the British Association Meeting in considering the negative result of the Report as not satisfactory. They thought that some statement on the subject should be laid before the Society, seeing that the Chapelhall Shell-bed had been so prominently brought before its notice in recent years.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH NOVEMBER, 1894.

ANNUAL GENERAL BUSINESS MEETING.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

The HONORARY SECRETARY (Mr. Murdoch) read as follows:—

REPORT OF THE COUNCIL FOR 1893-94.

Time with its never-ceasing current has again brought round the commencement of another session with the accompanying Business Meeting, at which it has been the custom for many years past for the Secretary to read, on behalf of the Council, a short review of the year just ended.

MEMBERSHIP.—During the 36th Session—the past one—the membership roll has more than held its own against the constant encroachments of time. This happy result has been attained largely owing to the exertions of Mr. John Dansken, one of the Society's Vice-Presidents, who has been the means of adding a number of both life and ordinary members to the list. Notwithstanding this favourable state of matters, the Council hope that members will not relax their individual efforts to enlist new members, so that the strength of the Society may be increased, with the result of enlarging the income, making greater additions to the library, and otherwise benefiting the various schemes of work.

MEETINGS.—The meetings held during the session were 9 in number—from October to May inclusive—and the average attendance was good. Many specimens of interest and value were brought forward for exhibition, and in not a few instances the accompanying "notes" might very probably have been classed as short "papers." A fair number of papers were read, sufficient to occupy all the available time set apart for the purpose, and, as in previous sessions, by far the larger proportion of them referred to our

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own west country field. Amongst them may be mentioned:—"On a Fossil Plant Bed at Meikle Busbie, Ardrossan," by Mr. John Smith; "Notices of Lately Deceased Members," by Mr. James Neilson, the Hon. Secretary, and others; "A Ramble up the Maich Water, Ayrshire," by Mr. James S. M'Lennan; "Notes on a Mineral in a Fumerole," by Mr. John Smith; "On the Protoconch of *Orthoceras*," by Mr. John Young, LL.D., F.G.S.; "On the Dentition of Janassa, from East Kilbride," by Dr. R. H. Traquair; "Notes on a Cycling Tour from Kilmarnock to Castle Kennedy," by Mr. Robert Dunlop; "On Ctenostomatous Polyzoa in the Carboniferous Limestone Series of Western Scotland," by Mr. John Young, LL.D., F.G.S.; "On the Occurrence of Peat, with Arctic Shells, in Boulder-clay at Faskine, Airdrie," by Mr. Robert Dunlop; "Notes on the Geology of County Antrim," by Mr. James Neilson. [Many of these papers will be found printed in the *Transactions*, vol. x., part 1.] The two papers: "Notes on a Cycling Tour," by Mr. Robert Dunlop, and "Notes on the Geology of County Antrim," by Mr. James Neilson, were illustrated by a large series of photographic views thrown on a screen by the oxy-hydrogen lantern.

With the spread of photography and the facility it gives for the preparation of slides, the use of the lantern has become so general and so useful for the purpose of illustrating papers and lectures that it is a question whether the time has not now arrived when the Society should, like many others, possess a lantern of its own, so that on any evening the apparatus might be at hand for the exhibition of photographs taken by members.

Excursions.—The list arranged for last spring and summer was considerably extended beyond that of any previous year, and the good, and sometimes large, attendance showed that the increased number of excursions was appreciated by the members. They were as follows:—Saturday, 14th April, to Walkinshaw Pit, Paisley, conducted by Mr. J. Hamilton; Saturday, 28th April, to Bowling and Dumbarton, conducted by Mr. James White; Saturday, 12th May, Dockra and Nettlehurst, Beith, conducted by Mr. Robert Craig; Saturday, 26th May, Lendalfoot, Ayrshire, conducted by Professor Forster-Heddle; Saturday, 9th June, Campsie, Stirlingshire, conducted by Mr. John Young, LL.D., F.G.S.; Saturday, 23rd June, Maich Glen, Ayrshire and Renfrewshire, conducted by Mr. J. S. M'Lennan; Saturday, 11th August, Buchlyvie, Stirlingshire, conducted by Mr. James Anderson; Saturday, 25th August, Auchenharvie, Ayrshire, conducted by Mr. John Smith. The excursion to Maich Glen did not come off owing to stress of weather, but doubtless this interesting locality will be visited at an early date. Of the others the most notable were those to Lendalfoot, Ayrshire, which occupied a whole day; and to Campsie Glen, jointly with the Edinburgh Geological Society, which served as a commemoration of the issue of the Third Edition of the "Geology of the Campsie District" by Dr. John Young, the conductor of the excursion.

Besides the regular Saturday excursions there were four on Friday afternoons to accessible localities near Glasgow, as follows:—Friday, 20th April, to Temple Pit, Anniesland, conducted by Mr. Joseph Sommerville; Friday,

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4th May, to Hamilton Hill, conducted by Mr. James White; Friday, 18th May, to Bishopbriggs East Quarry, conducted by Mr. James White; Friday, 1st June, to Drumchapel, conducted by Mr. James Anderson. These were well attended, and seemed to fill a decided place in the Society's programme, as suitable for members who could not leave town on Saturday afternoons. The thanks of the members are largely due to all the gentlemen who so kindly undertook the conduct of the various excursions. It seems very desirable that some record, however short, of the proceedings at them should appear in the *Transactions*, and the Council would therefore ask the conductors to bear this in mind for the future, and to send a more or less full account of each day's work to the Hon. Secretary.

THE LIBRARY.—Some additions to the books have been made during the session, though not to such an extent as is desirable, and as would be possible if the Society's income was larger. The transfer of the Transactions and publications of foreign societies to the Mitchell Library has been mainly carried out, though not yet quite completed. Mr. James Steel has undertaken to prepare a book for noting all issues received from the various corresponding societies, and when this is once begun there will be no further delay in the transfer of all foreign works received in exchange by the Society. In connection with the affairs of the Library it falls to be mentioned, however unwillingly, that your Honorary Librarian, Mr. James White, has determined to resign, from the end of October, the position he has held for so long a time. As he was not to be moved from his fixed resolve—though strong efforts were made to that end—the Council agreed to accept the resignation, and to appoint in Mr. White's room Mr. James S. M'Lennan, for the unexpired term of office (two years). Mr. White has now held the Honorary Librarianship with much acceptance to the members for ten years, and the Council would therefore ask the members to accord him a warm vote of thanks for the way in which he has conducted the library work during his long period of office.

ASSOCIATE MEMBERS.—During the past session the subject of the admission of students as associates of the Society, at a very reduced rate of admission, was anxiously considered by the Council, and at the October meeting of this year (1894), it was unanimously agreed that students attending geological classes in Glasgow should be eligible as associate members for the current session at the reduced rate of 2s. 6d.; this to include the right to attend all meetings and excursions of the Society, and to the use of the library, but not to vote nor to receive copies of the *Transactions*. A proposal to offer a prize or prizes to the most successful students in the Science and Arts Examination who are associates of the Society is still under the consideration of the Council.

It is impossible to conclude a report for any session without having to allude to the removal by death of some of the more or less known members. This year not so many were taken away as in the immediately preceding one, but still one has to be noted—the late Mr. David Bannerman, a respected and influential citizen of Glasgow, who had been a member of the Society ever since 1867.

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The HONORARY TREASURER (Mr. John Wight, C.A.), then submitted his Report on the Finances of the Society, which gave a good account of its monetary affairs [for an abstract see page 386], and the retiring HONORARY LIBRARIAN (Mr. James White), made a short statement as to the Library and the work connected with it during the past year.

After a few remarks by various members, who signified their satisfaction at the Society's position, the Chairman moved that, as approved by the meeting, the Reports should be unanimously accepted, and this was agreed to. He then asked the members to accord a hearty vote of thanks to Mr. James White, the retiring Honorary Librarian; to the Honorary Secretaries, Messrs. James Barclay Murdoch and Gavin M. Pratt; and to the Honorary Treasurer, Mr. John Wight, C.A., for their services on behalf of the Society, and this was cordially responded to by all present.

The following gentlemen were elected to fill the vacancies occurring in the Council at this time:—as Vice-President, Mr. James Neilson; as Members of Council, Mr. James White, Mr. John Smith, Mr. John Renwick, and Mr. Adam Knox. To fill the vacancy in the Council caused by the election of Mr. Neilson to the Vice-Presidentship, Dr. S. Sloan was elected.

Messrs. John Boyd and David Pearson were elected Auditors for the current year.

Rev. T. M. Younghughes, 10 Hillside Gardens, Partick, was elected an Ordinary Member of the Society.

Mr. JOHN SMITH exhibited a number of specimens, including:—

1. Antimony Ore (Sulphuret of Antimony) from the brow of Hare Hill, New Cumnock. This hill rises to a height of 1950 feet, and the antimony mine is situated 300 or 400 feet below the summit, and at its mouth a large quantity of the ore is still lying. If we are to judge from this material the ore appears to be contained in a quartz vein of particular toughness and of a dirty-white colour. Through the quartz there are long slender prisms and minute particles of ore. In fact the ore appears to have mostly formed in long prisms, which appear as a rule to radiate from a point, and are of a bright silvery colour. The inter-spaces between the prisms are sometimes filled up with more amorphous-looking ore, but sometimes with a honey-coloured quartz. The prisms of sulphuret of antimony have in some cases been dissolved out from amongst the quartz, leaving hollow spaces; and occasionally the antimony only has been dissolved out, leaving the sulphur behind, partially filling the cavities. Antimony is used in medicine, also with lead forming an alloy from which type metal is made.

2. Facetted Quartzite Pebble, from Boulder-clay, Muirkirk. In the "Geology of India," 2nd edition, p. 120, the author states that "Many of the glaciated pebbles of this bed (Lower Carboniferous) shew a peculiarity which is rare in other glacial Boulder-clays. Instead of being smoothed and striated on one or two surfaces only, they have often a number of flat surfaces meeting at obtuse angles and each shewing a different direction of striation." Some of these facetted pebbles were figured in the *Geological Magazine*,*

* Vol. iii., 1886, page 492.

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and it is hardly possible that the facets shewn on them can have been produced by ice-action as contended for by the author above quoted.

The pebble here shewn from Muirkirk appears to have similar facets, which, however, have probably been produced not by ice-action but by pressure when it was enclosed in a conglomerate from which it was broken out, afterwards finding its way into the Boulder-clay. The only objection to this theory is the fact that there are no cracks radiating from the facets.

3. Indented Limestone Pebble, from Silurian rock, Shalloch Mill, near Girvan. In the conglomerate from which this pebble came there are a number of fossils which appear to be all derivative, corals, crinoids, molluscs, &c. One of the contained limestone pebbles was clearly indented by a small sub-angular block of lydian stone which lay close to it. It appears to have been indented without having been crushed or even cracked.

4. Indented and Cracked Quartzite Pebble, from Shewalton Moor, near Irvine. This pebble probably came from the great conglomerate bed at Portincross, in which so many similar ones are embedded. After being crushed it has been firmly re-cemented or it could not have resisted the pressure it must afterwards have been subjected to.

Mr. ROBERT CRAIG read a paper, entitled "Remarks upon 'Joints' or Natural Fractures in Limestones." [See page 210.]

A discussion on the points raised in the paper was taken part in by Messrs. M'Lennan, Blair, Neilson, Murdoch, and other members.

The HONORARY SECRETARY (Mr. Murdoch) read the continuation of his "Notes on the Recent Meeting of the British Association at Oxford," in which he gave details of some interesting excursions made under the leadership of Mr. A. H. Green,* Professor of Geology in Oxford, to a number of sections of local rocks, including Oolite, Lias, Purbeck Beds, Portland Beds, Kimmeridge Clay, Greensand, Oxford Clay, and River Gravels.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH DECEMBER, 1894.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

The following gentlemen were elected members of the Society. As Honorary Member:—Mr. James Thomson, F.G.S. As Ordinary Members:—(1) Mr. George Sneaton Goold, 9 Hillside Gardens; (2) Rev. G. A. Frank Knight, M.A., 11 South Park Terrace, Hillhead; (3) Mr. John Mackie, M.E., Crofthead, Neilston; (4) Mr. William Brown Thomson, Banker, Wishaw. As Associate Members:—(1) Mr. James Allan, 144 Buccleugh Street; (2) Mr. Arthur Briggs, 357 Springburn Road; (3) Mr. John Frew, 175 Hope Street; (4) Mr. W. B. Laughlan, 89 Queen Street; (5) Mr. Alexander M'Call, 248 Paisley Road; (6) Mr. D. M'Cowan, Dundashill House, Port-Dundas; (7) Mr. Alexander Ross, 14 Otago Street, Hillhead; (8) Mr. Archibald Shanks, Bridgend House, Dalry; (9) Mr. William S. Thomson, c/o Mr. R. T. Moore, 156 St. Vincent Street; (10) Mr. Hugh Boyd Watt, 4 North Court, Royal Exchange; (11) Mr. W.

* Since this date the regretted death of Prof. Green has occurred

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H. G. Campbell Dickson, 314 Renfrew Street; (12) Mr. H. M. Middleton, 10 Park Avenue; (13) Mr. Daniel Suttie, Jordanhill; (14) Mr. R. H. Turnbull, 120 Nithsdale Road, Pollokshields; (15) Mr. E. A. Troup, 10 Park Avenue; (16) Mr. John C. Niven, 10 Park Avenue; (17) Mr. Robert Anderson, 9 Leslie Street, Pollokshields; (18) Mr. Adam Henderson, 9 Leslie Street, Pollokshields; (19) Mr. Robert M'Donald, 143 Watt Street; (20) Mr. Alexander Murdoch, 16 Devon Street; (21) Mr. Archibald Y. Neilson, 9 Hillside Gardens, Partick; (22) Mr. John Paterson.

Mr. JOHN SMITH exhibited a number of specimens, as follows:—

1. Black Interglacial Sandstone from a Cutting on the Newmilns and Darvel Railway, a short way west from Darvel Bridge. This specimen was from a thin bed interstratified in fine sand. The original sand-bed had evidently been impregnated with iron as a binding agent, some of the iron still existing in the form of bright spicular crystals.

2. Grey Postglacial Sandstone from Longford, near Kilwinning. This rock occurs on the side of the Garnock Water, near the G. & S.-W. Ry. Co.'s bridge, as a thin shelving rock washed by the tide, and interstratified in a loose sand-bed. Whether it has been solidified by iron or lime has not yet been determined.

3. Raised-Beach Sandstone from Ferriter's Cove, on the south-west coast of Ireland. This rock occurs as a thin bed in the shore-sands, and contains many land-shells, principally *Helix*, in fine preservation. It has been hardened by carbonate of lime infiltered by rain-water from the decomposition of a bed of marine shells with sand, which have been blown up from the beach by the action of the south-westerly gales, and deposited on top of the Raised-beach bed.

4. Diatom and Sponge Spicule Deposit from Loch Doon, Ayrshire. About a hundred years ago the Loch was lowered by a mine being driven through the greywacke rock at the head of Glen Ness, and amongst other things exposed was a deposit which contained diatoms and sponge spicules, under a bed of peat. In the upper part of the bed the diatoms appear to have been destroyed by the iron which pervades it, though the sponge remains are abundant. The lower, and light-coloured, portion of the bed is a nearly pure mass of diatoms and spicules in splendid preservation. As it can only be reached when the water is very low the thickness has not been ascertained. When first laid bare a lot of it was used by neighbouring farmers as marl, and the inhabitants also soon found out that it makes a capital polishing material for metal-work.

5. Fine Gravel from the top of Ardeer blown sand-hills. Some of the quartz pebbles are ¼-inch long, and flint chips, blown up from the implement-bearing gravelly hollows to the west, are nearly ½-inch long. That the action of the wind could raise these small heavy masses to such a height is wonderful. The Permian red sandstones of Mauchline, now so much used as building-stone, contain layers of gravel very similar in appearance to the above, and appear to have been formed from desert-blown sand.

Remarks upon several of the specimens exhibited by Mr. Smith were made by Dr. Young, F.G.S., and other members.

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Mr. HENRY TAYLOR read a paper entitled "Notes upon the Geology of the Island of Eigg." It was illustrated by coloured diagrams, and by a large series of rock-specimens. [This paper will be printed in the next part of the *Transactions*.]

Remarks were made upon the subject by Messrs. Neilson, Sommerville, and Dr. John Young, F.G.S.

Mr. JAMES NEILSON read joint papers by Mr. Joseph Wright, of Belfast, and himself, on "Boulder-clay, a Marine Deposit," and "On the Occurrence of Marine Organisms in Boulder-clay near Glasgow." [See pages 263, 273.] They were illustrated by a diagram, and by a large series of mounted specimens of the organisms which had been discovered, and which were shown under the Society's microscope.

Mr. JAMES WHITE read a paper "On Boulder-clay," in which, after giving a description of the appearance and position of our local deposits of Boulder-clay, he reviewed the various theories which from time to time had been brought forward to account for their formation.

Discussion on these various papers was adjourned to next meeting.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH JANUARY, 1895.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

On the motion of Mr. James White, seconded by Mr. Mathew Blair, it was agreed that £10 of the Society's funds should be devoted to the purposes of the Library during the current session.

Mr. Robert W. Dron, M.E., 79 West Regent Street, was elected an Ordinary Member, and Miss Sophia B. Robbie, an Associate Member, of the Society.

Mr. Joseph Sommerville exhibited a specimen of rock from No. 6 Pit, Garscube, at Temple, showing Cone-in-cone structure, and remarked that he had brought it for exhibition as presenting appearances which could not be accounted for by the theory laid before the Society, and afterwards published in the *Transactions*, by Dr. John Young, F.G.S.* In the present specimen the structure was seen to be in two shaly layers—one above and the other below an 8-inch seam of ironstone, and, according to miners, common in this state over all the district to the north and west of Glasgow.

Dr. YOUNG vigorously defended his theory of the formation of Cone-in-cone, and said he thought it was quite sufficient to account for the appearances in the present specimen. The ironstone in it was not a continuous stratum, but a portion of a lenticular nodular mass, and the original layer which contained the cone-in-cone structure had been gradually warped round and under the ironstone nodule during its formation at this part, the result being an appearance of two distinct layers. Other speakers followed, the discussion exciting a good deal of interest, and a number of other specimens of cone-in-cone were exhibited.

* *Transactions*, vol. viii., part I., page 1.

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Mr. JOHN SMITH read a paper, entitled "Charred Coal, with Graphite, and Discovery of Diamonds in the Graphite at Craigman, near New Cumnock." [See page 257.]

Mr. SMITH also read a paper on "Dry River Channels in the Neighbourhood of Muirkirk" [see page 331]. His remarks were illustrated by a raised model of the district cut by himself from a block of wood.

Several members took part in a subsequent discussion on this paper, and it was thought that, as the locality was an interesting one, an excursion might be made to it during the coming session.

The adjourned discussion upon the papers read at the December meeting by Messrs. Wright and Neilson (see pages 263, 273), and by Mr. James White, was then entered upon, remarks being made by Dr. Young, Messrs. Blair, Anderson, M'Lennan, Sommerville, Steel, Cooke, White, and Murdoch. Several of the members said that since December last they had washed specimens of Boulder-clay from the localities named in the first-mentioned papers, but had not been successful in finding any organisms. The opinion expressed by others was that there was some doubt as to the nature of the samples investigated by Mr. Wright, and that further enquiry was absolutely necessary. It was therefore agreed to appoint a committee to take fresh specimens of undoubted and undisturbed Boulder-clay from various localities, including those named in Messrs. Wright and Neilson's papers, and to submit them to an exhaustive examination, bringing up the results at a future meeting.

The following members were appointed as a Boulder-clay Committee:—Messrs. Joseph Sommerville, James Neilson, James White, William Armour, and James Steel (convener), with power to add to their number.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH FEBRUARY, 1895.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

The HON. LIBRARIAN (Mr. M'Lennan) announced that the President of the Society (Sir Archibald Geikie, F.R.S.) had presented an almost complete set of "Nature" to the library, and a vote of thanks was passed to the President for his handsome gift.

Mr. JOHN SMITH exhibited specimens of Graphite and other minerals as follows:—

1. Graphite from Ceylon. This form of graphite, which occurs in metamorphic strata, is very pure, and has probably resulted from the alteration of a coal-bed by heat. It is a brilliant variety, being built up of thin scaly crystals, such as are often got from blast furnaces when making No. 1 pig-iron; particles of it readily adhere to the fingers, giving them a "black-leaded" appearance. Graphite in this form crystallizes in thin flexible hexagons.

2. Graphite from Travancore. This variety is much the same as the last, only it looks more compact, the scaly crystals being much smaller.

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3. Graphite, "Keesh," from a Blast Furnace. This variety comes out of the furnaces both with the slag, "black dirt," and iron, especially when No. 1 pig-iron is being made. When the iron is very *rich*, numerous scales of graphite are squeezed out to the surface of the "pigs" on cooling, often having their faces covered with corroded-looking little holes. Many of these scales are so light as to float in the air. The bright scales exhibited had been mounted for about a dozen years, but did not appear to have tarnished in the smallest degree.

4. A Sword-shaped piece of Clayband Ironstone from Waterland, Ayrshire. When a miner was breaking a lump of ironstone, this very strangely-shaped specimen fell off. It measures 19 inches long by 1⅝ inch at its widest part, but has evidently been longer, and probably pointed at one end. It is curved, double-edged, the edges being remarkably sharp, the surface pretty smooth, but the sides not exactly symmetrical. Its peculiar shape has resulted from the meeting of two joints which are curved in three directions. In rocks there are various systems of regular joint-planes, as Mr. Craig recently explained to the Society (see page 210); but various other forms of jointing occur sparingly, and sometimes take strange shapes, as in the present specimen.

5. Chonicrite from Belhamie Serpentine Quarry, Colmonell, Ayrshire. Dr. Heddle describes chonicrite as "massive; crystalline-granular and globular-radiated; hardness, 2·5 to 3·; weak silky white, with yellowish spots; greenish-blue.

Chemical composition—	Alumina, - -	17·1
	Magnesia, - -	22·6
	Lime, - - -	12·6
	Silica, - - -	35·7
	Water, - - -	9
		97·0

Fuses before the blow-pipe easily, with intumescence, to a grey glass; decomposed by hydrochloric acid with separation of silica."

The specimen seems spotted with dark serpentine, and is 3½ inches wide, being the full width of the vein from which it was taken. The exfiltration vein in this quarry runs up to several inches in thickness, and occurs in dark-greenish serpentine, to which it is soldered. The serpentine forms a large part of the hillside, and is conspicuous from the large quantity of enstatite crystals it contains. The chonicrite vein is cut up by many joints, mostly with slickensided surfaces. This does not occur from faulting, as the sides of the vein are quite entire, so that the slickensiding must have been caused by some sort of molecular creeping. Last year many specimens of the chonicrite were lying about, but it was most difficult to get a sizeable specimen showing the full thickness of the vein, as a slight touch of a hammer caused them to fall to pieces along the slickensided joints. Some bits from a vein 1¼ inch wide, which were lying about, were firmer.

6. Chonicrite(?) from Bowertrapping Dolerite Quarry, Dalry, Ayrshire. In this quarry at present may be seen a vein, several inches wide, reaching

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from top to bottom of the rock. About 10 feet of the lower part is mostly filled by a substance resembling the Belhamie mineral (No. 5 above), only rather greener. I sent a specimen of this to Prof. Heddle, who said that if not chronicrite he did not know what it was. It is much more solid than the thick Belhamie vein, and in this respect resembles the thinner vein there. It also tarnishes more readily on exposure to the air, and this specimen is much darker than when first obtained.

Mr. JOHN YOUNG, LL.D., F.G.S., contributed a series of "Observations on the Leading Geological Characteristics which distinguish the Group of Carboniferous Rocks in Western Scotland." With the aid of maps, diagrams, and sections, he pointed out the relations of the several divisions of the strata to each other, their mineral and fossil characters, and their connection with the associated groups of contemporaneous and intrusive volcanic rocks which form such important geological features within and around the borders of the various Scottish coal-fields. He further pointed out the clearly existing evidence that the whole of our coal-field strata had been slowly accumulated over an area of depression which had extended across Central Scotland; and that the numerous coal-seams, thick and thin, clearly indicated the old land-surfaces on which the successive vegetations, now mineralized into coal, once flourished. He also stated that while the sandstones, limestones, shales, and ironstones, which alternate with the coal-seams, clearly show the several depressions over the coal-areas in which the aqueous sedimentary strata were afterwards deposited, the fossils they contain afford proof as to their respective marine or freshwater formation; and that such varying conditions are characteristic of all the strata lying between one coal-seam and another; these strata in each case representing the land-surfaces and sedimentary deposits of the period.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH MARCH, 1895.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

The following gentlemen were elected members of the Society:—As a Life Member—Major John Cassells, 62 Glencairn Drive, Pollokshields; as an Ordinary Member—Mr. Alexander M'Connell, C.E., 167 St. Vincent Street; as an Associate Member—Mr. Adam Gowans Whyte, 8 Holyrood Quadrant.

Mr. JAMES NEILSON, *V.-P.*, exhibited a number of specimens, including Plant-remains, Coal, and Chalk Flints, from Ardtun in Mull, and Chalk Flints from Iona, and regarding their occurrence he made some explanatory remarks.

Mr. JOHN SMITH read a paper, entitled "A New View of the Arran Granite Mountains." [See page 216.] It was illustrated by a model of the granite area cut in wood by the author.

At the close of the paper an animated discussion was taken part in by Dr. John Young, F.G.S., Messrs. Cooke, Neilson, and other members, some of whom did not agree with the conclusions drawn by Mr. Smith from his observations.

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SPECIAL MEETING.

SOCIETY'S ROOMS, 207 BATH STREET, 27TH MARCH, 1895.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

Mr. HENRY M. CADELL, F.G.S., &c., Hon. Sec. of the Edinburgh Geological Society, gave a lecture in the Large Hall "On Mountain Forms and Structures." It was illustrated by a series of lime-light views, shown by the oxy-hydrogen lantern.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH APRIL, 1895.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

A congratulatory vote to Dr. David Robertson, the veteran naturalist of Cumbrae, long a member and latterly an Honorary Associate of the Society, on his receiving the degree of LL.D. from the University of Glasgow, was unanimously passed.

Mr. L. C. COOKE exhibited specimens of Coal from a solitary thin seam occurring at a depth of 20 fathoms in the Upper Carboniferous Limestone of Derbyshire, and made some remarks upon its occurrence.

Dr. YOUNG, F.G.S., said he thought that from its bright and glossy fracture, this was a true land-coal, like the cherry coal of Lanarkshire, and that it therefore indicated a short elevation of the sea-bottom at the time of its formation.

Mr. ROBERT DUNLOP exhibited several specimens of Ayrshire fossils, contributed by Mr. Andrew Sinclair, Kilmaurs, including a *Limulus* (allied to the King Crab, and very rare in the West of Scotland) from Woodhill Quarry, Kilmarnock, and a Trilobite from a quarry near Kilmaurs.

Mr. W. H. G. CAMPBELL DICKSON exhibited specimens of Fulgurites, tubes formed by the passage of lightning through sand, from Witsand, Hill District, Griqualand, South Africa, and made some interesting remarks upon them. Mr. Joseph Sommerville said that, though an old member of the Society, he did not remember such forms having ever been shown at any of the meetings, and Dr. Young expressed himself to the same effect. Mr. John Smith said he had frequently examined the Ardeer sand-hills, and other likely localities, after thunderstorms, in the hope of finding similar forms, but as yet without coming across the slightest traces of them.

Mr. John Smith gave a short summary of his paper on "Arran Granite," read at last meeting (see page 216), stating, (1) previous knowledge as to Arran granites; (2) theories propounded as to their formation and present state; and (3) what he claimed to have added on both these points.

Mr. L. C. Cooke, Dr. Young, the Chairman (Mr. Neilson), and other members joined in the subsequent discussion, several pointing out objections they entertained to the author's conclusions.

Mr. JOHN YOUNG, LL.D., F.G.S., read a paper, entitled "Notes on the Ostracoda found in the Lacustrine or Freshwater Strata of the Campsie

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District, which alternate with the Lower Beds of the Carboniferous Marine Limestone Series." [See page 334.]

A number of sections which showed the peculiar arrangement of the Entomostracan shells in the rock were afterwards shown by Dr. Young under the Society's microscope.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MAY, 1895.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

On the motion of Mr. Mathew Blair, seconded by Mr. Joseph Sommerville, it was agreed that a sum of £3, from the Society's funds, should be devoted to purchase a prize or prizes to be awarded to members or associate members, who, attending geological classes in the city, were the most successful students in the Science and Art examinations of the year.

Mr. Archibald M'Coll, slate quarry manager, Ballachulish, was elected an Ordinary Member of the Society.

Mr. DUGALD BELL, F.G.S., read a paper on "The High-level Shelly Deposits, and their bearing on the Question of Submergence; with Special Reference to the Recent (Third) Edition of Dr. James Geikie's 'Great Ice Age.'" [For an abstract, see page 346.]

At the close of the paper an animated discussion was taken part in by several members.

SOCIETY'S ROOMS, 207 BATH STREET, 30TH MAY, 1895.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

The following lady and gentlemen were elected Ordinary Members of the Society:—Mrs. Fingland, 15 Broomhill Avenue, Partick; Mr. Alexander Glen, 25 Dumbreck Road; Mr. Hugh Manners, Airdrie Academy, Airdrie; Rev. Frederick Smith, 76 Grafton Street; Mr. Oliver Styles, 105 Buccleuch Street.

Mr. Joseph Wright, F.G.S., of Belfast, read a further communication upon "The Lower Boulder-clay, a marine deposit," [see page 270] of which the former part had been read at the previous December meeting. The paper was illustrated by a large series of drawings, diagrams, and comparative tables.

At its close a discussion was taken part in by Messrs. Neilson, *V.P.*, Dugald Bell, F.G.S.; James Thomson, F.G.S., Sommerville, Steel, Murdoch, and Dr. Young, F.G.S. A hearty vote of thanks was afterwards passed to Mr. Wright for his kindness in crossing the Channel to read his paper to the members.

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PROCEEDINGS FOR SESSION, 1895-96.

(38TH SESSION.)

SOCIETY'S ROOMS, 207 BATH STREET, 17TH OCTOBER, 1895.

Mr. WILLIAM ARMOUR, C.E., *Vice-President*, in the Chair.

In opening the proceedings the Chairman congratulated the members upon their once more meeting to begin the work of another campaign. The last session had been a successful one, and he hoped and expected that the new one now beginning would prove equally, if not more interesting, and useful. He stated that, with the view of encouraging the study of geology, the Council had arranged to continue the system of Associate Membership, begun last year, by which any student attending geological classes in Glasgow might enjoy all the benefits of the Society's meetings, excursions, and library, at a very small subscription. This boon to students, which had been largely taken advantage of in last session, would probably be still more popular in the present one.

Mr. R. W. DRON, C.E. and M.E., exhibited several specimens of Altered Dolerite, which had taken the place of a coal-seam, from a coalpit in South Ayrshire, where it occurred at a depth of 130 fathoms. Similar intrusions are found in the Lanarkshire coal-field, where the dolerite, from its colour, is known as "White Horse." Protruding itself from some dyke it runs laterally above or below a coal-seam or other stratified rock, burning it more or less, and sometimes rendering it columnar. In the course of its progress it usually thins out, loses its crystalline appearance, and becomes white and soft, sometimes even assuming almost the character of a pipe-clay, in which state the miners' wives use it for their hearths and doorsteps.

Mr. JAMES NEILSON, *V.P.*, read a paper on "The Old Red Sandstone and Carboniferous Rocks of the North End of Arran," a criticism upon some of the statements regarding these rocks in the last (1893) edition of Sir Archibald Geikie's "Text-book of Geology." [See page 280.] The paper was largely illustrated by sections, maps, and specimens, and fossils from the district under review.

At the close of the paper, a telegram received by the Hon. Secretary from Sir Archibald Geikie was read as follows:—"To Secretary, Geological Society, 207 Bath Street, Glasgow. Statement about Arran Limestones corrected. See Annual Report, Science and Art Department, 1894, page 284.—GEIKIE." [See page 299.]

An animated discussion was then taken part in by Dr. John Young, F.G.S., Messrs. Dugald Bell, F.G.S., Sommerville, Macnair, the Chairman (Mr. Armour), and other members, some of the speakers contending that, however far the statements in the "Text-book" might be at fault, Mr. Neilson had not succeeded in proving the relationships of some of the strata described in his paper. In replying to these criticisms, Mr. Neilson said that, up till the moment Sir A. Geikie's telegram had been read, he was not aware that any correction of the statements he had challenged had ever been made.

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SOCIETY'S ROOMS, 207 BATH STREET, 14TH NOVEMBER, 1895.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

The Report of the Council for the past year was read by the Honorary Secretary (Mr. Murdoch) as follows :—

REPORT OF THE COUNCIL FOR 1894-1895.

It is once more the duty and the privilege of the Council to submit to the members a short summary of the work and state of the Society during the past year—the 37th of its existence.

The MEMBERSHIP has rather more than held its own, but, as stated on previous similar occasions, the Council still think there is room for an advance in this direction. More new members mean more new books and magazines, and generally more advantages to every one connected with the Society, so that individual effort in this matter is clearly desirable in every member's interest.

The FINANCES of the Society will be spoken of by your Hon. Treasurer. Suffice it here to say that the income has been more than able to meet the expenses, though, of course, expenditure is never unnecessarily incurred in any department.

MEETINGS.—The ordinary meetings of the past session were nine in number—with a special one—all of which were well, some of them even largely, attended, and there was always enough of material brought forward in the shape of specimens with accompanying notes, and papers illustrated by specimens, maps, and diagrams, to occupy the whole time available for each meeting.

PAPERS AND NOTES ON SPECIMENS.—Of these many of interest and value were submitted to the meetings. Amongst them may be mentioned :—

"Evidences of the Most Recent Glaciers in the Firth of Clyde District," by Mr. James Anderson [see page 198]. "Remarks upon 'Joints' or Natural Fractures in Limestones," by Mr. Robert Craig [see page 210]. "The Geology of the Island of Eigg," by Mr. Henry Taylor. "Boulder-clay, a Marine Deposit," two papers, by Mr. Joseph Wright of Belfast [see pages 263, 270]. "On the Occurrence of Marine Organisms in Boulder-clay near Glasgow," two papers, by Mr. James Neilson [see pages 273, 278]. "Charred Coal with Graphite," by Mr. John Smith [see page 257]. "On Boulder-clay," by Mr. James White. "Observations on the Leading Geological Characteristics which distinguish the Group of Carboniferous Rocks in Western Scotland," by Dr. John Young, F.G.S. [for a short summary, see page 364]. "A New View of the Arran Granite Mountains," by Mr. John Smith [see page 216]. "Notes on the Ostracoda found in the Lacustrine, or Freshwater, Limestone of the Campsie District," by Dr. John Young, F.G.S. [see page 334]. "On the High-Level Shelly Deposits, and their bearing on the Question of Submergence"; with Special Reference to the Recent (Third) Edition of Dr. James Geikie's "Great Ice Age," by Dugald Bell, F.G.S. [for an abstract, see page 346].

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It will be noticed as a feature that in almost all cases these papers treat of geological phenomena and observations in Western Scotland; while the specimens exhibited, with their accompanying notes, are similarly mostly local, which shows that members of the Society do not require to go far afield for interesting material.

The EXCURSIONS for the year were as follows :—

Balgray Hill, Great Western Road, on Saturday, 16th March, conducted by Mr. John Renwick, when the Cuttings and Tunnel on the new Lanarkshire and Dumbartonshire Railway were visited, showing sections of Laminated-clay with Shells, Boulder-clay, Sandstone, Shale, and Gas-coal.

Ardrossan and Saltcoats, Ayrshire, on Saturday, 20th April, conducted by Mr. John Smith, when the following were visited :—A Shell Mound, Columnar Trap, Trap with Sandstone Veins, and the Lower Ironstone, at Ardrossan. The Upper Limestone, Volcanic Ironstone, and the Upper Coal and Trap Rocks were seen at and near Saltcoats.

Burntisland, Fifeshire, on Saturday, 4th May, conducted by Mr. H. M. Cadell, F.G.S., *Hon. Sec.* of the Edinburgh Geological Society, with which body this was a joint excursion. During the afternoon the Volcanic Ash and Interbedded Trap Beds were visited, and afterwards the Fossiliferous Shales and Burdiehouse Limestone. In the evening the members of the two societies had tea together at Burntisland.

Beith, Ayrshire, on Saturday, 18th May, conducted by Mr. Robert Craig, when various quarries in the Lower Carboniferous Limestones, more or less fossiliferous, were visited.

Glen Roy, Inverness-shire, on Thursday, 23rd May, conducted by Mr. James Neilson. This, on the Queen's Birthday holiday, was taken as a whole-day excursion by the Highland Railway to inspect the famous Parallel Roads of Glen Roy, on which various papers have been read before the Society [see *Transactions*, vol. viii., pages 40, 72, &c.] Till the opening of the new Highland Railway last year, it was impossible to visit this district and return to Glasgow under three days. On the present occasion the excursion was accomplished in one.

Maich Glen, Ayrshire and Renfrewshire, on Saturday, 1st June, conducted by Mr. James S. M'Lennan. This excursion was taken in lieu of one arranged for the previous year to the scene of the conductor's paper read before the Society in 1893 [see page 121]. During the day the Lower Coal measures and sections of Coal, Ironstone, Limestone, and underlying Igneous Rocks were inspected.

Tullich Hill and Ben Reoch, Loch Long, Dumbartonshire, on Saturday, 15th June, conducted by Mr. John Renwick. The Highland Railway was also utilized for this excursion, a stoppage of the mid-day train at Glen Douglas being courteously arranged by the Railway Company's officials. Railway cuttings through Metamorphic Rocks were well seen, also sections of Felsite Dykes, Boulder-clay, &c. The party returned from Arrochar station.

The Spout of Ballagan, Stirlingshire, on Saturday, 3rd August, conducted by Mr. Joseph Sommerville. The North British Railway conveyed the

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party to Strathblane. At the famous "Spout" were seen the Calciferous Sandstone series, with Limestone, Sandstone, and Shale sections, and examples of Bedded Trap and Trap Dykes.

Gourock, Renfrewshire, on Saturday, 17th August, conducted by Mr. James White. Leaving the train at Fort Matilda, the route was taken to Gourock, near where exposures of the Calciferous Sandstones—including Sandstones and Volcanic Ash beds—were seen.

The Heads of Ayr, on Saturday, 22nd June, conducted by Mr. Robert Dunlop. This was an extra excursion, arranged jointly with the Ayr Natural History Society, to visit some of the fine exposures of the Calciferous Sandstones and Volcanic Rocks of the Ayrshire coast.

The above which were all well, and some of them largely, attended, prove that the excursions continue to be amongst the most popular and interesting features of the Society's programme.

There were, in addition to these, several Friday-evening excursions to localities in or near Glasgow, which, as the similar ones of last season, were found useful by members who could not command Saturdays. These were all conducted by Mr. James White, to whom, as well as to all the other conductors of excursions, the thanks of the members are largely due.

The LIBRARY will be reported upon by Mr. J. S. M'Lennan, who succeeded Mr. White on his retiral last year after a long term of office. During the past autumn an arrangement has been made with Mr. Martin of the Philosophical Society, by which members can take out or exchange books from our library on any weekday from 10 a.m. to 5 p.m. As books could previously only be had on the nights of meeting, the Council believe that the new arrangement will be a great boon to members, and encourage them to make greater use of the library.

TRANSACTIONS.—A new part (vol. x., part 1), though unavoidably delayed for a short time, is now nearly all printed, and will, it is hoped, be shortly ready for issue. The following part has also been begun, and will contain many of the papers mentioned in this report as read during last session, as well as those of the current one. It will therefore bring the publication of papers almost, if not quite, up to date.

ASSOCIATE MEMBERSHIP.—During last year a new departure was taken by the Council, with the approval of the Society, in arranging to admit as associate members students who were attending Geological classes in Glasgow. It was fixed that the charge for admission should be a nominal one, and it was also resolved that several prizes should be awarded to the most successful associates at the Science and Arts Examination.

The Council feel warranted in making similar arrangements for the new session—1895-96—and the teachers of Geological classes have therefore been asked to place the matter before their students as soon as possible.

The HONORARY TREASURER (Mr. Wight) then read his Financial Statement for 1894-95. [For an abstract see page 387.]

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The HONORARY LIBRARIAN (Mr. M'Lennan) read as follows:—

REPORT ON THE WORK OF THE LIBRARY FOR 1894-95.

Your Librarian has to report that, on taking office, he found the Library in good order, and that he has endeavoured to keep it in the same condition. The demand for books has been fairly good—volumes to the amount of 150 having been borrowed by 40 members and associates.

During the year some 25 new books have been bought, involving a cost of nearly £7—the best scientific books being costly.

The transfer to the Mitchell Library of the Foreign Transactions received in exchange from Societies on the Continent and elsewhere has run through, the efforts of the Committee being completely carried out. The arrangement for the future is that a book in which all the titles and dates are regularly entered is kept. This is put in a box where the publications are placed, and when they are called for by the messenger he initials each item he takes away with him.

The Librarian now also keeps a book in which the title and date of all English exchanges are regularly entered. This will not only check the receipt of the various publications, but will facilitate their cataloguing when desired.

An arrangement by which Mr. Martin of the Philosophical Society is enabled to give out books during the week ought to make the Library more accessible, as well as lead to greater interest being taken in it, and consequently to more benefit being derived from it by the members and associates of the Society.

After the various reports had been read, they were unanimously approved on the motion of Mr. Joseph Sommerville, seconded by the Chairman, and a hearty vote of thanks was awarded to the Honorary Secretary, Mr. James Barclay Murdoch; the Assistant Honorary Secretary, Mr. Gavin M. Pratt; the Honorary Treasurer, Mr. John Wight, C.A.; and the Honorary Librarian, Mr. James S. M'Lennan, for their continued services on behalf of the Society.

Office-bearers to fill the vacancies occurring at this time were elected:—As Vice-President—Mr. James Anderson. As Members of Council—Messrs. William Armour, C.E., Prof. Thomas King, Mr. David Pearson, and Mr. Joseph Sommerville. To fill a vacancy caused by the retiral of Dr. Samuel Sloan from the Council, Mr. William Maclay was elected. Messrs. John Boyd and John R. M'Farlane were appointed auditors for the current year.

The following gentlemen were elected Ordinary Members of the Society:—Mr. Arthur Briggs, Banker, 357 Springburn Road; Rev. Alexander Brown, 4 Leslie Drive, Pollokshields; Mr. Alexander Forbes, Lecturer on Mining, Tweedsdale, Castlehill Road, Ayr; Mr. Peter Macnair, 16 Martyr Street; and Mr. John Robertson Gow, 12 Renfield Street.

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Mr. JOHN SMITH exhibited specimens from Dalry, Ayrshire, as follows:—

1. Feather alum from Auchenskeith. This substance occurs in three beds at this locality, their position in the section being as follows:—

	Feet.	Inches.
1. Upper Limestone Bed,	0	0
2. Dark Alum Shale,	2	6
3. Coal,	0	6
4. Light-coloured Fireclay,	5	0
5. Limy Shale,	2	1
6. Lower Limestone Bed,	0	0
7. Dark Alum Shale (not now seen),	0	0
8. Coal (equivalent of the Hurlet and Campsie seam),	0	0

The dark shale (No. 2) appears to contain a large quantity of alum, and weathers away at about the rate of 3 inches per annum; that is to say, about 3 inches scale off from the face of the bed every year, and that without the intervention of rain-wash. It may be helped a little by frost, though possibly that may retard the weathering, the face of the bed under the limestone ledge being quite dry. At one place in the quarry the face of the shale is 9 feet further in than that of the limestone rock, this weathering being entirely due to the formation of feather alum crystals, the face of the shale being often white with them. On the other hand, the face of the coal-bed is frequently yellow from the decomposition of pyrites, which occurs to a small extent both in the coal and in the shale. In the fireclay bed (No. 4) there does not appear to be so much alum as in the shale bed, the crystals in it appearing in fine white silky bundles, and also in greenish-coloured aggregates, the latter being tinted by sulphate of iron. The crystals may often be found splitting open small nodules, half being fixed on to one end of a sheaf of crystals, and the other half attached to the opposite end. The fireclay bed, which is light-coloured, weathers yellow, with orange tints on the surface. In the lower alum shale bed—the equivalent of the Hurlet and Campsie seam—alum shale is not at present seen in the quarry.

2. Magnesian (?) Limestone Nodules, from Auchenskeith. These occur in the fireclay bed (No. 4), often reaching to over a foot in diameter. They are made up of clusters of small globules, generally a little larger than a pin-head, but sometimes much smaller, which at their points of contact squeeze one another into various shapes. They are traversed by thin dark veins apparently of later formation, one vein often cutting through several globules. The surfaces of some of the nodules show a development of larger globes massed together like some varieties of kidney hematite, or like the concretionary forms assumed by dolomite, although the relief of the globes is not so prominent as in it. When heated to redness, cooled, and wetted, the globules fall asunder.

3. "Silvery" *Productus (P. melobesus)*, from Auchenmade. The fine silvery spines of the *Productus* are well known. It is probable that when the animal was alive the spines were not "silvery." Some examples show an outer light-grey layer above the silvery one, but these are exceptionally

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rare. The "silver buckie" of the sea-shore only gets its name after it has been rolled sufficiently to part with its outer covering.

Mr. JAMES NEILSON, *V.P.*, exhibited a number of specimens of *Pholas* and *Saxicava*, from Millport and other localities in the Firth of Clyde, with their chambers or burrows excavated in limestone and in volcanic ash, also one bored in calcite in volcanic ash, and as the latter rock had proved too tough for the art of the little mechanic, the result was that the excavation was quite lopsided.

The question was afterwards discussed as to the means by which these boring molluscs make their excavations in the rock, whether mechanical or chemical, or a combination of both—and Dr. Young and Mr. John Smith gave their reasons for believing that the action is purely mechanical, the instrument employed being the foot of the animal probably with the help of sand-grains.

Mr. JOHN SMITH read a paper "On a Globular Structure in a Patch of Shale enclosed in the 'Deil's Dyke,' near Greenan Castle, Ayrshire." [This paper will be printed in the next part of the *Transactions*.]

The HON. SECRETARY (Mr. Murdoch) read a short descriptive paper on "The Proceedings of the late Meeting of the British Association at Ipswich," which he had attended as the Society's delegate. He mentioned a number of the more interesting papers read in Section C (Geology), and gave details of various excursions which had been made to local rock-sections.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH DECEMBER, 1895.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

The following gentlemen were elected members of the Society:—As Ordinary Members—Mr. David Chalmers, 6 Raeberry Street; Prof. T. Rhymer Marshall, 11 Woodside Crescent; Mr. G. R. Thomson, Assoc. R.S.M., B.Sc., Lecturer on Geology in the Technical College, 204 George Street; Mr. John Wise, 170 Bellfield Street. As Associate Members—Mr. John Cowan, 175 Hope Street; Mr. Hugh Boyd Watt, 4 North Court, Royal Exchange; Mr. Hugh Brown, 34 Gray Street; Mr. Matthew Blacklock, 2 Royal Terrace, Springburn; Mr. David F. Finlayson, 461 Sauchiehall Street; Mr. Archibald Leitch, Ardmaleish, Port-Glasgow; Mr. Alexander M'Call, 2 Tulliallan Place, Paisley Road; Mr. Donald M'Cowan, Dundashill House, Port-Dundas; Mr. John M'Lintock, 214 New City Road; Mr. J. S. Motherwell, 48 Carnarvon Street; Mr. Alexander Murdoch, 16 Devon Street.

The undernoted Associate Members, who had passed highest at the Science and Art Examination in Geology, May, 1895, were presented with handsome books, being the prizes arranged to be awarded by the Society to the most successful students:—Mr. Robert Anderson, 9 Leslie Street, Pollokshields; Mr. W. H. G. Campbell Dickson, 314 Renfrew Street; and Mr. R. H. Turnbull, 120 Nithsdale Road, Pollokshields.

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Mr. JOHN YOUNG, LL.D., F.G.S., exhibited (1) specimens of two species of Crustaceans belonging to the genus *Cyclus*, small shield-like shells from the rich fossiliferous limestones of Trearne, near Beith, and which had not previously been recorded from any of the western Scottish limestones.

He also showed (2) a collection of mounted specimens of the larger Ostracoda, a group of small bivalve crustaceans, of which about 20 species have been noted from Trearne alone. The chief interest attaching to these specimens is that they represent some of the largest forms of the group found in Britain, and that seven of the species exhibited had not previously been recorded from Scottish limestone strata.

Dr. Young exhibited (3), from the same locality, the valves of a spinose form of *Aviculopecten*, in which some of the spines, and the bases of others, were still seen remaining on the ribs of the shell, a feature rarely found on examples from other localities.

Mr. JOSEPH SOMMERVILLE exhibited specimens of Marcasite with Fibrous Alum, in shale, from the Upper Coal measures, and gave some particulars of its composition and occurrence.

Several remarks as to the distribution of the mineral in Scotland were afterwards made by Prof. Marshall, Dr. John Young, F.G.S., and Mr. John Smith.

Mr. JOHN SMITH read a paper "On a Section of Carboniferous Strata exposed in a Cutting of the Caledonian Railway, near Lissens, three miles north of Kilwinning." [This paper will be printed in the next part of the *Transactions*.]

At its close remarks on points raised in the paper were made by Prof. Marshall, Dr. John Young, F.G.S., and other members.

SPECIAL MEETING, LARGE HALL, 207 BATH STREET, 19TH DECEMBER, 1895.

Prof. JOHN YOUNG, M.D., in the Chair.

SIR ARCHIBALD GEIKIE, F.R.S., Director-General of the Geological Survey of Great Britain, *President* of the Society, gave a Presidential Address to the members and their friends on "The Latest Volcanoes of the British Isles" [see page 179]. The paper was illustrated by a large series of maps and diagrams.

At its close, on the motion of Mr. Dugald Bell, F.G.S., a hearty vote of thanks was awarded to Sir Archibald Geikie for his Address, and for his kindness in coming specially from London to deliver it.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH JANUARY, 1896.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

The following gentlemen were elected Ordinary Members of the Society:—Rev. William Reid, F.C. Manse, Hurlford; Mr. Adam Gowans Whyte, 1 Holyrood Quadrant.

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Mr. JOHN SMITH exhibited specimens as follows:—(1) Concretion from Sand below Boulder-clay at Sevenacres, Kilwinning; (2) Tachylyte, with worm-like gutters on its weathered surface, from Lendalfoot, Girvan; (3) Chrysotile from Serpentine rock *in situ*, at Gamesloup, near Lendalfoot; (4) Annelid tube in a growth of *Lithostrotion* in Carboniferous limestone, from Armagh, Ireland. [The notes on these specimens will be given in next part of the *Transactions*.]

Mr. JAMES S. M'LENNAN read a paper on "The Coast-line of Berwickshire, from Eyemouth on the North to Marshall Meadows Bay on the South" [see page 337].

A discussion followed, and was taken part in by various members.

Mr. JAMES WHYTE read a paper, entitled "Stray Thoughts on the Glacial Epoch," in which he reviewed the present state of the question of submergence, and the various theories put forward by different writers on the subject. He said he was inclined to support the astronomical theory of Sir Robert Ball, which contained numerous points harmonising with, and accounting for, the known conditions of the problem, glacial epochs being just as much a part of the constitution of things as summer and winter, or day and night.

In the following discussion, Mr. Dugald Bell, F.G.S., and other members, while complimenting the author on his paper, dissented in various instances from his statements and conclusions.

Mr. BELL spoke of the loss geological science had just sustained in the comparatively early death from typhoid fever of Mr. Hugh Miller, an esteemed member of the staff of the Scottish Geological Survey, and son of the well-known author of "The Old Red Sandstone." In connection with, and outside of, the Survey work, the deceased gentleman had done much good solid geological work which gave promise of leading to still higher performance, a hope now unfortunately blasted.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH FEBRUARY, 1896.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

On the motion of the CHAIRMAN, seconded by Mr. Joseph Sommerville, it was unanimously agreed that a sum not exceeding £10 of the Society's funds should be devoted to library purposes during the current session.

Mr. JOHN SMITH read a paper, entitled "The Great Submergence: My Interpretation of the Clava Section, Inverness-shire." This section, which contains a thick bed of shelly-clay, at a height of 503½ feet above sea-level, had lately been examined by the Committee of the British Association on High-level Shell-beds, but their finding was not unanimous, the majority Report being that the shelly-clay at Clava is in the position in which it was deposited on the sea-bottom; while the minority Report was that the shells contained in the bed had been transported from a lower level by ice from Loch Ness, then an arm of the sea. The author of this paper supported

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the conclusions of the majority, holding it to be physically impossible that the shelly-clay with stones, or even the shells themselves, could have been carried uphill by ice, seeing that neither the shells nor the stones bore marks of striation. He urged that the statements made by Mr. Dugald Bell, F.G.S., in the *Geological Magazine*, in support of the Report of the minority (of which he was the only member who had seen the section), viz., that the shelly-clay had been deposited in an extra-glacial lake, into which had been dropped and accumulated fine mud, rounded stones, shells, and other material carried by the ice-sheet, could not be maintained. He held that the shelly-clay of the Clava section is an undoubted marine deep-water deposit, laid down under still conditions. If it had been deposited in a high inland freshwater lake, it must have contained abundant remains of vegetable matter, molluscs, ostracods, diatoms, and other forms of freshwater organisms, whereas the fact really was that it did not hold any vestiges of organic life except such as were of marine origin. [This paper will be printed in the next part of the *Transactions*.]

At its close Mr. Dugald Bell, F.G.S., who was secretary of the Committee appointed by the British Association for the Investigation of High-level Shell-beds, and who, with Mr. P. F. Kendall, issued the minority Report upon the investigation of the Clava-beds, gave his reasons for this course, afterwards expressing his disagreement with a number of Mr. Smith's statements and conclusions.

Further discussion on the subject was postponed to the following meeting.

Mr. PETER MACNAIR read a paper on "The Altered Basic Rocks of the Highlands as exemplified by the Sill of Hornblende Schist underlying the Loch Tay Limestone" [see page 302]. The paper was illustrated by a series of maps, sections, and diagrams, rock-specimens and microscopic sections, the latter being shown in a number of microscopes kindly lent for the occasion.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH MARCH, 1896.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

Mr. George M'Crie, 16 Sardinia Place, Hillhead, was elected a Life Member, and Mr. Wm. S. Thomson, c/o R. P. Moore, C.E., 156 St. Vincent Street, an Ordinary Member, of the Society.

Mr. PETER MACNAIR exhibited a series of specimens of *Palæospondylus Gunni*, a fossil fish (?) recently discovered at Achanarras in Caithness, and read some notes on its occurrence by Mr. James Reid, Blairgowrie, from whose collection the specimens came. This interesting organism has been described principally by Dr. Traquair and Mr. Smith-Woodward, both of whom consider it to be allied to the lampreys. Dr. Bashford Dean also says that *Palæospondylus* seems unquestionably to be a lamprey. Sir William Dawson, however, compares it with certain small Carboniferous batrachians. From the form of skull, the absence of well-defined paired

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fins, and the presence of spines (posteriorly), *Palæospondylus* appears to show a close affinity to modern marsipobranch fishes. The notes were illustrated by a number of drawings.

The adjourned discussion upon the High-Level Shell-beds at Clava was resumed by Mr. John Smith, who gave a short summary of his paper read at the February meeting, stating that he adopted the theory of a submergence of at least 500 or 600 feet, with a possible maximum of 2000 feet during the glacial epoch.

Some remarks were also made by Mr. James Neilson, *V.P.*, Mr. Joseph Sommerville, Dr. John Young, F.G.S., and other members.

Mr. John Smith read "Notes on Mr. Dugald Bell's Reply to My Paper on the Great Submergence," stating that the chief point in dispute was the question whether the shelly-clay at Clava had been deposited on a sea-bottom or in an upland freshwater tarn. His answer, or rather the answer of the shell-bearing clay itself was very distinctly that it had been deposited on a sea-bottom. The bulk of the shells, which are all marine, are perfect, the epidermis being in many instances still attached. Had they been carried uphill from Loch Ness by land-ice—a distance of about ten miles—probably very few, and those only in fragments, would have survived the journey. Land-ice would doubtless drag stones and clay along with it, but every stone, even to pinhead particles, would become striated. In the shell-bearing clay at Clava, not a single striated shell had, so far as he knew, been found, and not more than three or four striated stones.

Mr. Dugald Bell, F.G.S., then read a paper, entitled "Additional Notes upon Clava," in which he re-stated concisely his reasons against the "Great Submergence" theory on the one hand, and his arguments for the ice-transport theory on the other—for example, the absence of any traces of the sea over the country generally, not only at high levels, but at intermediate ones. This absence of sea-traces was very remarkable, and indeed unaccountable, on the submergence theory, for the sea leaves behind it traces not easily obliterated, not to speak of the relics of marine organisms which it contains. This objection, while applying to the country generally, was of peculiar force with regard to the district around Clava, to the "Great Glen" in its immediate neighbourhood, and to the numerous side-glens where, as advocates of submergence had themselves admitted, traces of sea-occupation would in all likelihood have been preserved. It seemed incredible that where the sea to the depth of some 500 feet should have swept to and fro through the "Great Glen" for, doubtless, a prolonged period, it yet should have left no marks of itself on the hills on either side, and no deposits recognisable as marine, either there or in any of the side-glens. To get quit of this difficulty various theories had been formed, but none of them were feasible, or at least supported by sufficient evidence. Mr. Bell then proceeded to consider the alternative theory of the transport of such rare and exceptional deposits as those of Clava to their present position by land-ice. There were difficulties, no doubt, as to this also, but he thought nothing to the same extent or weight as those against

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the adoption of the submergence theory. And there were a good many points in its favour. There were the striking evidences of ice-action all over the district that the ice-sheet came from the direction of a former sea-bottom; that it rose in its progress, carrying numerous boulders up with it; and that many instances are known and admitted of a transport of marine shells and masses of shelly-clay by such agencies, and under similar conditions. The deposit at Clava was thus naturally accounted for by means proved and admitted to have been in operation at one time, without having recourse to an immense geological change of another kind, highly improbable in itself, and for which there is no separate and independent evidence. The remainder of the paper was devoted to an exposition of the author's own suggestion that there had been at this point an extra-glacial lake, extending along the side of the ice-sheet, and into which the materials of the shelly-clay had been gradually accumulated. This suggestion appeared to be a highly probable one, and capable of explaining a number of the more puzzling features of the Clava deposit, as for example the "deep still water," which seemed to be one of the essential conditions of the deposit, and for which, in the absence of some such explanation as he had suggested, a very "great submergence" would evidently be required.

At the close of this paper an animated discussion upon the whole question was taken part in by Messrs. Dunlop, Macnair, Dr. John Young, F.G.S., the Chairman, and other members.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH APRIL, 1896.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

Mr. JAMES STARK, S.E., 10 Hillhead Gardens, Partick, was elected an Ordinary Member, and Mr. Stephen Hutcheson, 99 Hill Street, an Associate Member, of the Society.

Mr. JOHN YOUNG, LL.D., F.G.S, exhibited (1) a series of Microscopic Slides mounted by a method which he had recently adopted, so as to show without much trouble the minute forms of crystalline structure which characterize the glassy Pitchstone Rocks of Arran, and which afford such beautiful and interesting objects for examination owing to their great and varied resemblance to minute forms of vegetable life. This method consists in crushing small portions of the rock between the jaws of iron pincers, and selecting the thinnest and most transparent fragments, which are afterwards neatly mounted on the usual form of glass slide, within a circle, and covered with Canada balsam, being then left for a time to harden and dry. They are then surrounded by a circle punched out of thin cardboard, which is gummed to the slide and furnished with a thin glass cover to protect the mounted flakes from dust. These fragments, if carefully selected, will appear under the microscope as little pictures of the various crystalline structures—each differing somewhat from the other,

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owing to the varying angles of fracture of the rock. The process is simpler and easier than the tedious old plan of cutting and grinding sections of the hard glassy rock to a thin transparency. Dr. Young also shewed in illustration of the above a number of drawings of the fern-like forms seen in pitchstone which were made by Mr. Samuel Allport, F.G.S., and published in the *Geological Magazine* for January, 1872.

Dr. Young then exhibited (2) a specimen of Crystalline Quartz filling a Drusy Cavity in trap-rock, found in a quarry near Bridge of Weir, Renfrewshire. The specimen, which measures about 9 inches in length by 3 inches in width across its largest outer angle, has the inner walls of the cavity lined with numerous well-formed crystals of quartz, but its chief interest lies in the peculiar markings which stud the whole of the outer walls of the druse. These markings are imprinted over the surface of the quartz, and are seemingly the counterparts of a crystalline structure which once formed, or coated, the walls of the druse, but now no longer exist. They look very like the impressions which would be made by crystals of calcite, or carbonate of lime, of the hobnail variety. This would imply that after the formation of the cavity its inner walls were coated with a lining of calcite crystals, their place being probably then taken by thermal waters holding silica in solution. From this silica the quartz crystals now seen filling up the inner cavity of the druse would be afterwards developed, except at its wider end, till the silica had also ceased to be deposited within the druse before the filling up was completed. Long afterwards, during the decay and weathering of the trap-rock, the lime-crystals which had formed on the outer walls of the druse were dissolved away by eroding waters, leaving no traces of their existence beyond their impress on the base of the subsequently-formed quartz layer, which gave the outer walls of the druse a honeycombed appearance, the casts of the quartz standing out in relief with sharp edges between the lime crystals. This interesting specimen had been presented to the Hunterian Museum by Mr. George Barlas, a member of the Society.

Mr. PETER MACNAIR read a joint paper by Mr. James Reid, Blairgowrie, and himself, "On the Genera *Lycopodites* and *Psilophyton* of the Old Red Sandstone Formation of Scotland" [see page 323]. The paper was illustrated by a large series of specimens from Caithness, Strathmore, and Canada, by drawings by the authors, and by sections of the plant-remains shown under the Society's microscope.

SOCIETY'S ROOMS, 207 BATH STREET, 7TH MAY, 1896.

Mr. JOHN DANSKEN, F.S.I., *Vice-President*, in the Chair.

Mr. ROBERT ANDERSON, 19 Rupert Street, was elected an Associate Member of the Society.

Mr. JAMES NEILSON, *Vice-President*, read an account of the Society's recent excursion to Calderwood Glen, when the members visited and examined the limestone and cementstone sections, rendered classic by

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the Rev. David Ure in his "History of Rutherglen and East Kilbride," published in 1793, the first reliable work on local geology, and one which has not lost its interest and value up to the present day.

Mr. JOHN YOUNG, LL.D., F.G.S., exhibited specimens and sections of a peculiar Cream-coloured Felspathic Rock, from a boulder on the shore of Brodick Bay in Arran. They were crowded with small spheres of hæmatite, or peroxide of iron, of a reddish-brown colour, which gave the rock quite an oolitic-looking structure. These spheres were probably originally segregated in the rock as a carbonate of iron, which subsequently altered to a peroxide, the alteration being due probably to heat from igneous action. Though not unknown in one or two other localities in Western Scotland, this Arran instance was the only one Dr. Young knew of in which the iron existed as a peroxide, though as a carbonate in the form of spheres it sometimes occurred. The strong contrast in colour between the iron and the whitish felspathic base of the rock rendered it a conspicuous object when polished or newly fractured. Some specimens which had been rubbed smooth were shown. These left a strong stain of a rich "Venetian red" on white paper, being themselves of a reddish-brown colour. Small boulders of the rock are found, somewhat rarely, along the north-eastern shore of Brodick Bay, and the rock is believed to occur *in situ* somewhere on Maoldon Hill, south of Corrie. The specimens exhibited were collected last summer by Mr. Thomas Young, M.D., of Manchester, a son of the exhibitor.

Mr. PETER MACNAIR exhibited a series of Rock-specimens and Microscopic Sections in illustration of a paper on "The Altered Basic Rocks of the Highlands," which he had read before the Society in February last. [See page 302.]

The HONORARY SECRETARY (Mr. Murdoch) read on behalf of the author, Mr. John Smith, a paper "On the Occurrence of Pumice Pebbles in the Raised-beaches of Ayrshire" [see page 349]. The paper was illustrated by specimens of the pumice pebbles, and by microscopic sections.

A discussion followed, being taken part in by Dr. John Young, F.G.S., Mr. R. Dunlop, Mr. Stark, and other members, who agreed generally with the author's conclusions.

Mr. DUGALD BELL, F.G.S., read a paper, entitled "Additional Notes on Glen Fruin." He alluded to his having first observed the remarkable moraine in Glen Fruin in 1889-90, describing it afterwards to the Society and in the *Geological Magazine*. He at that time indicated certain mounds on the western or south-western side of the glen as in all probability a "continuation of the same moraine." Since then, in a paper read to the Society, and afterwards printed in the *Transactions* [in 1893], a description of the southern portion of the moraine had been given by Mr. John Renwick, accompanied by, more or less, a claim for its discovery, with which he [Mr. Bell], as the original writer on the subject, and as having specially mentioned the portion in question, was by no means inclined to acquiesce. He admitted there was ground for difference of opinion as to the precise mode of formation of the moraine: whether by a glacier

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in the ordinary sense, or by an ice-sheet of some extent clinging to the hills and partly occupying the upland valleys subsequent to the period of maximum glaciation. Also, if by land-ice in its usual form, as to whether it proceeded westwards from Lochlomond, or came in from the north-west by Lochlong, the Gareloch, and Glen Fruin. From the evidence furnished by the glaciation of the district generally, the latter was most probably the case; but he saw none that the ice-sheet came, or could come, westward from Lochlomond. There seemed to be nothing that could compel it to take that direction even if open to it, which was doubtful) just at the broadest part of its channel, and with an ample extent of low ground opening before it. On the contrary, there was every proof that the Lochlomond ice was being constantly pressed eastward by the influx of ice from the mountainous region to the west. Mr. Bell then examined at some length the statements and arguments which had been employed in favour of the theory of the western motion of the ice at this point, commenting on their inconclusive character and the absence of any definite facts to support them. But whatever theory might ultimately be accepted as to the formation of the moraine, he apprehended in no degree affected the priority of observation regarding its existence.

The author of the paper referred to, Mr. John Renwick, briefly replied, and stated that while still claiming to be the first to call attention to the existence of a defined line of moraine mounds on the south side of Glen Fruin, running almost due east up the hillside, and not mentioned by Mr. Bell in his former paper nor indicated on his map, he denied he had in any way attempted to appropriate the credit which accrued to Mr. Bell as the original writer on the Glen Fruin moraine.

SOCIETY'S ROOMS, 207 BATH STREET, 28TH MAY, 1896.

Mr. JAMES ANDERSON, *Vice-President*, in the Chair.

On the motion of Mr. James Neilson, *V.P.*, seconded by Mr. William Armour, C.E., the meeting agreed that a sum of Two Guineas from the Society's funds should be given towards the upkeep of the Millport Marine Station.

Mr. JAMES NEILSON, *V.P.*, exhibited several specimens of Prehnite from cuttings on the new Lanarkshire and Dumbartonshire Railway, near Bowling, showing Impressions of Calcite Crystals which, originally deposited on the interior surfaces of cavities in the rock, had afterwards disappeared.

Some remarks on the specimens were also made by Dr. Young, F.G.S.

Mr. JOHN SMITH read a paper on "The Drift (or Glacial) Formation in Ayrshire."* In Ayrshire a great series of drift beds is found to extend from below sea-level up to 1061 feet of altitude, probably to over 1700 feet, and to attain a thickness of over 100 feet. These beds are capped by

*The original title of this paper was "The Interglacial Formation in Ayrshire," but as the author has since discovered marine shells in both the upper and lower Boulder-clays referred to, he has been obliged to alter it.

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Boulder-clay with large blocks, extending from below, up to 1005 feet above, sea-level, where this deposit overlies the lower Boulder-clay, and either it, or perhaps both, extend to over 1700 feet of altitude. These drift beds, where best developed, are made up of upper Boulder-clay, with marine shells at parts; sand and gravel; shelly pebbly clay (marine); gravel, sharp sand, muddy sand, pebbly clay (one or two beds) and laminated mud with marine shells at places; and sometimes lower Boulder-clay with marine shells. In certain places there are gravels both above and below the Boulder-clays. On the top of the rock under the lower Boulder-clay there occurs sometimes a thin bed, which might be called *original ground moraine*, evidently a product of valley glacier-ice. In the Irvine Valley and its side-streams, the shelly exposures occur at 40 feet, and up to nearly 600 feet above sea-level. In some of the scaurs on the Ayr Water and its side-streams repeated exposures of the shelly beds can be traced from a little above Ayr (not far above sea-level), to an altitude of 1061 feet above tide-mark. In the Lugar, Burnock, Glenmore, and Guelt valleys, shelly exposures occur at many places, up to 880 feet in the latter place. On the Coyle Water they extend up to 920 feet. Shelly beds are also found on the Doon, in the glens about Girvan, Lendalfoot, Currarie, and in coast sections about Ballantrae. In some of the sandy beds there are occasional shells, generally in a decomposing state, and in these beds boulders 4 feet in diameter have become quite *rotten* from the action of percolating acidulated water, so that under these circumstances it is not surprising to find shells in a state of decay, or to find that they are altogether absent. The shells in the Boulder-clays are often in a remarkably fine state of preservation, and frequently have the epidermis attached. The great bulk of them, however, occur as crushed fragments—the pieces as a rule being *sharp-edged*, often with the epidermis, so that no doubt the breakage was caused by the stones which fell from floating-ice on to the sea-bottom during the deposition of the stony clays. In districts where the clays are *very* stony, shells are exceedingly rare or apparently absent. There is a greater proportion of perfect small shells than of large ones, probably because the former were better sheltered between the stones. Shelly fragments are sometimes scratched and polished. In the sand and mud-beds boulders are sometimes got, the largest one seen by Mr. Smith being 4 feet in diameter. At about 60 feet above sea-level he found a thin bed of peat (1 inch thick) under 3 inches of sand in Boulder-clay, and at 820 feet he saw another thin layer of peat in a sand-bed, both probably drifted patches which bore evidence that there had been a land-surface covered with vegetation and free from ice, but he detected no deposits that could be positively claimed to be of fresh-water origin. The paper was illustrated by a map of the district, sections, photographs, and a large collection of shells from the deposits under review. [It will be printed in the next part of the *Transactions*.]

At its close a discussion was taken part in by Dr. John Young, F.G.S., Messrs. Robert Craig, M'Lennan, Neilson, *V.P.*, Dugald Bell, F.G.S., and the Chairman.

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SOCIETY'S ROOMS, 207 BATH STREET, 11TH JUNE, 1896.

Mr. JAMES NEILSON, *Vice-President*, in the Chair.

Mr. JAMES STARK exhibited a specimen of Pumice-stone which a friend had picked up floating on the Indian Ocean months after the great eruption of Krakatoa, from which locality it had probably drifted.

Mr. JAMES THOMSON, F.G.S., read a paper "On the Occurrence of Species of the Genus *Palastræa* in the Lower Carboniferous Limestone of Scotland, with a Description of some New Species and Notices of Varieties."

At its close, some remarks were made by Dr. Young, F.G.S.

Mr. THOMSON then read a paper "On the Stratified Rocks of the Shoreline from Clachland Point to the Cock of Arran," which was illustrated by a sectional diagram. [Both of Mr. Thomson's papers will be printed in the next part of the *Transactions*.]

Remarks on the various points raised in the paper were afterwards made by Mr. James Neilson, *V.P.*, and by other members; also by the Rev. Mr. Landsborough, Kilmarnock, who was present as a guest.

The CHAIRMAN then declared the 38th session to be closed.

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THE JUBILEE OF LORD KELVIN.

On the 16th of June, 1896, a most interesting ceremony in connection with the fiftieth anniversary of Lord Kelvin's occupancy of the Chair of Natural Philosophy, in the University of Glasgow, was held in the Bute Hall—the presentation to his Lordship of an extraordinary number of Congratulatory Addresses by representatives of Universities, learned societies, and public bodies of the British Empire and foreign countries all over the world.

As it was thought to be only fitting that the Geological Society of Glasgow should not be behind hand in doing honour to his Lordship—its President for a very long term of years—the Council agreed that an Address should be prepared, and that the present President, Sir Archibald Geikie, F.R.S., and the Honorary Secretary, Mr. James Barclay Murdoch, should attend the ceremony as Delegates on behalf of the Society. This they had the honour of doing, as well as of presenting the Address to Lord Kelvin.

The original Address—a facsimile of which will be found on the opposite page—was signed by all the office-bearers for the time being. It was engrossed on vellum, and was enclosed in a neat morocco case, stamped with the Society's device.

In reply, Lord Kelvin sent the following letter:—

The University,
Glasgow.

For the Address which I have had the honour to receive from the Geological Society of Glasgow on the occasion of the Jubilee of my Professorship of Natural Philosophy in the University of Glasgow, I desire to express my warmest thanks. I value very highly the great honour which it has conferred upon me. The friendly appreciation of my scientific work contained in the Address is most gratifying.

I feel deeply touched by the great kindness to myself, and the good wishes for my welfare, of which it gives an expression.

6th July, 1896. Kelvin

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To The Right Honourable Lord Kelvin, D.C.L., LL.D.,

Professor of Natural Philosophy in the University of Glasgow, Past President of the Royal Society, etc., etc.

My Lord

The Geological Society of Glasgow desires to take part in the universal expression of congratulation on the occasion of your attaining the fiftieth year of your Professorship in the University of Glasgow, and to express to you its heartiest sympathy and good wishes.

For twenty-one years, the Society had the honour and privilege of having you as its President. While the Society cannot but look back with pride upon your connection with its history, it especially desires to express on the part of geologists, the admiration which is felt for the contributions you have made to the progress of sound Geology. Your remarkable papers "On Geological Time," "On the Internal Condition of the Earth as to Temperature, Fluidity and Rigidity," and on other important subjects have enriched the Society's Transactions, and won the admiration of geologists at home and abroad. There is no field of science which you have entered, that has not felt the vivifying influence of your genius, and Geology furnishes a singularly striking example of this influence.

That you may long live to adorn the University on which you have conferred such lustre and to enrich the whole realm of science with brilliant discovery and pregnant suggestion is the ardent wish of the Society.

We have the honour to be,

My Lord,

Yours faithfully

Arch Geikie

President

John Dansken F.S.I.; F.R.A.S.
James Neilson
J. W. Anderson

Vice Presidents

Council.

Thomas King
Willm Armour Ch.
P. Marlay
John Renwick
Joseph Sommerville
Smith
Jas Barclay Murdoch
Hon. Sec.

Matthew Blair
Adam Knox
Robert Dunlop
D. Pearson
Jas S. McLennan
Gavin M. Pratt
John Wright Hong Treas

Society's Rooms, 207 Bath St.,
Glasgow, 12th June, 1896.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,			£40	0	0	
,, in Treasurer's hands,			4	15	5	
						£44 15 5
Life Members' Subscriptions,						36 15 0
Subscriptions for current year, and Arrears (10/),						75 0 0
Interest,						7 13 9
Publications sold,						3 15 9
Legacy from the estate of the late Sir M. Connal, £10—						
Paid to account,						2 5 0
						£170 4 11

EXPENDITURE.

Reprinting Dr. Young's paper, "Geology of Campsie,"						£20 8 4
Rent, Insurance, and Attendance,		£13	2	6		
Collector's Commission,		2	17	0		
Printing Circulars, &c.,		5	18	9		
Disbursements by Secretaries and Librarian,		6	3	0		
Subscription to Palæontographical Society,		1	1	0		
Petty charges,		0	16	2		
					29	18 5
New Books, and Binding,					8	12 5
Cash in Bank,	£110	0	0			
,, in Treasurer's hands,	1	5	9			
				111	5	9
				£170	4	11

STOCK ACCOUNT.

To Balance to Credit,					£781	5 9
By Cash in Bank and on hand,					£111	5 9
,, Funds Invested,					170	0 0
,, Property—						
Books,	£440	0	0			
Furniture, Bookcases, and Microscope,	60	0	0			
Fossils, not valued,	0	0	0			
				500	0	0
				£781	5	9

GLASGOW, 29th October, 1894.—Examined and found correct, the balance in Treasurer's hands being £1 5s. 9d.

JOHN BOYD,
D. PEARSON, } *Auditors.*

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ABSTRACT OF TREASURER'S ACCOUNTS FOR YEAR ENDING 30TH SEPTEMBER, 1895.

CASH ACCOUNT.

RECEIPTS.

Cash in Bank,	£110 0 0		
Cash in Treasurer's hands,	1 5 9		
		£111	5 9
Life Membership Subscriptions,		10	10 0
Subscriptions for current year, and Arrears (£3 10s.),		82	0 0
Subscriptions in Advance,		1	10 0
Associate Subscriptions,		3	0 0
Interest on Funds,		8	1 11
Publications sold,		0	16 6
Legacy from late Sir Michael Connal: second instalment,		1	2 6
Note—The Legacy was £10, of which £3 7s. 6d. has been paid.			
		£218	6 8

EXPENDITURE.

Plates for *Transactions*,		£1	4 6
Rent, Insurance, and Attendance,	£12 10 0		
Collector's Commission,	2 17 9		
Postages and Petty Expenses,	1 4 7		
Printing Circulars, &c.,	9 17 6		
Lantern Expenses for Two Lectures,	1 7 6		
Disbursements by Secretaries and Librarian,	10 0 6		
		37	17 10
New Books,		6	13 0
Cash in Bank,	£170 0 0		
Cash in Treasurer's hands,	2 11 4		
		172	11 4
		£218	6 8

STOCK ACCOUNT.

To Balance to Credit, subject to the expense of the *Transactions* presently in the Press,		£842	11 4
		£842	11 4

By Cash in Bank and on hand,		£172	11 4
,, Funds Invested,		170	0 0
,, Property—			
Books,	£440 0 0		
Furniture, Bookcases, and Microscope,	60 0 0		
Fossils, not valued,	0 0 0		
		500	0 0
		£842	11 4

GLASGOW, 25th October, 1895.—Examined and found correct, the balance in Treasurer's hands being £2 11s. 4d.

D. PEARSON,
JOHN BOYD, } *Auditors.*

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OFFICE-BEARERS, 39th SESSION—1896-97.

President—SIR ARCHIBALD GEIKIE, F.R.S.

Vice-Presidents.

For Three Years.	*For Two Years.*	*For One Year.*
ROBERT DUNLOP.	JAMES ANDERSON.	JAMES NEILSON.

Council.

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WILLIAM MACLAY.	JAMES STEEL.	JOHN SMITH.
WILLIAM SINCLAIR.	DAVID PEARSON.	JOHN RENWICK.
JAMES STARK.	JOSEPH SOMMERVILLE.	ADAM KNOX.

Hon. Treasurer—JOHN WIGHT, C.A., 150 Hope Street.

Hon. Librarian—JAMES S. M'LENNAN, Oswald School, Jordanhill.

Hon. Secretary and Editor of Transactions—JAMES B. MURDOCH, F.R.Ph.S.E., Capelrig, Mearns.

Assistant Hon. Secretary.—GAVIN M. PRATT, 62 Bothwell Street.

Publishing Committee.

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WILLIAM ARMOUR.	GAVIN M. PRATT.
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Auditors.

JOHN R. M'FARLANE.	G. R. THOMSON.

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LIST OF MEMBERS, 1896.

Honorary Members.

Year of Election.

1865. Geikie, Sir Archibald, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of Great Britain and Ireland; Museum of Practical Geology, Jermyn Street, London, *President.*

1867. Jones, T. Rupert, F.R.S., F.G.S., 17 Parson's Green, Fulham, London, S.W.

1867. Kirkby, James W., Allithwaite, Sunderland.

1867. Woodward, Henry, LL.D., F.R.S., F.G.S., Natural History Department, British Museum, South Kensington, London.

1867. M'Chesney, Joseph H., Professor of Geology, University of Chicago, U.S.

1871. Hull, Edward, M.A., LL.D., F.R.S., F.G.S., &c., formerly Director of the Geological Survey of Ireland, 20 Arundel Gardens, Notting Hill, London, W.

1872. Lord Kelvin, Right Hon., LL.D., F.R.S., Professor of Natural Philosophy, University of Glasgow.

1872. Young, John, M.D., Professor of Natural History, University of Glasgow.

1879. Hunter-Selkirk, John R. S., LL.D., Daleville, Braidwood, Carluke. [1864]*

1883. Judd, J. W., F.R.S., F.G.S., Science Schools, South Kensington, London, S.W.

1885. Heddle, M. Forster-, M.D., F.R.S.E., Emeritus Professor of Chemistry and Mineralogy, St. Andrews.

1888. Murray, John, LL.D., F.R.S.E., of the "Challenger," 32 Queen Street, Edinburgh.

1889. Argyll, His Grace the Duke of, Inveraray Castle, Inveraray.

1884. Thomson, James, F.G.S., 6 Stewart Street, Shawlands, Glasgow.

1896. Craig, Robert, King Cottage, Beith. [1867]

* The date *after* a name is that of previous election as an ordinary member.

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Honorary Associates.

Year of Election.

1867. Struthers, Thomas, Gourock. [1859]
1871. Horne, James, 71 Carlton Hill, St. John's Wood, London. [1858]
1871. Farie, James, Canonbury, London. [1859]
1878. Lapworth, Charles, LL.D., F.G.S., Professor of Geology, Sir Josiah Mason College of Science, Birmingham.
1883. Traquair, R. H., M.D., F.R.S.E., F.G.S., Museum of Science and Art, Edinburgh.
1883. Geikie, James, LL.D., F.R.S.E., F.G.S., Professor of Geology and Mineralogy, University of Edinburgh. [1873]
1886. Robertson, David, LL.D., F.L.S., F.G.S., Fernbank, Millport. [1867]

Corresponding Members.

1859. Dougall, John, M.D., 115 Paisley Road, Glasgow.
1860. Sommerville, George, Thornliebank.
1862. Hunter, James, Ironmaster, Coltness.
1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.
1865. Winchell, Alex., Professor of Geology, University of Michigan, U.S.
1866. Gloag, Rev. Dr. Paton J., 28 Regent Terrace, Edinburgh.
1866. Myers, Rev. Edward, F.G.S., 20 Summerhill Terrace, Birmingham.
1867. Kerr, David, Wemyss Colliery, Fifeshire.
1871. Jack, R. L., F.G.S., Government Geologist, Geological Survey Office, Queensland.
1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.
1871. Kinahan, G. H., Geological Survey of Ireland, Dublin.
1871. Ward, John, F.G.S., 23 Strafford Street, Longtown, Staffordshire.
1878. Stewart, Rev. Alex., LL.D., F.S.A.Scot., Ballachulish Manse, Nether-Lochaber.
1883. Lindström, Professor G., State Museum, Stockholm, Sweden.
1883. Scott, Thomas, F.L.S., 14 Lorne Street, Leith Walk, Edinburgh. [1880]
1883. Smith, W. Anderson, Ledaig.
1884. Dobbie, J. J., M.A., D.Sc., Professor of Chemistry and Geology, University College, Bangor, North Wales. [1876]
1884. Nathorst, Dr. Alfred Gabriel, Geological Survey Office, Stockholm, Sweden.

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Ordinary and Life Members.

Year of Election.

1868. Allan, Archibald B., C.E., Hillock House, Govan Road, Govan.
1882. Anderson, James, 164 Buchanan Street, Glasgow, *Vice-President.*
1881. Armour, William, C.E., 207 West George Street, Glasgow.

1875.*Bain, Sir James, 3 Park Terrace, Glasgow.
1894.*Barlas, George, 15 Ruthven Street, Kelvinside, Glasgow.
1891. Barnett, James Rennie, Lilybank House, Johnstone.
1894.*Barr, Prof. Archibald, Royston, Dowanhill.
1894.*Barr, James, M.I.C.E., F.S.I., 221 West George Street, Glasgow.
1893. Barr, Patrick, 51 Bath Street, Glasgow.
1881.*Barr, Thomas M., C.E., Caledonian Railway, Perth. [1858]
1858. Bell, Dugald, F.G.S., 27 Lansdowne Crescent, Glasgow.
1859. Bennie, James, Geological Survey of Scotland, George IV. Bridge, Edinburgh.
1889. Blair, Matthew, 5 Hampton Court Terrace, Garnethill, Glasgow.
1887. Boyd, John, Mount Blow, Maxwell Drive, Pollokshields, Glasgow.
1882. Brand, John, 81 Gloucester Street, Glasgow.
1895. Briggs, Arthur, Banker, 357 Springburn Road, Glasgow.
1895. Brown, Rev. Alexander, 4 Leslie Drive, Pollokshields, Glasgow.
1887. Brown, Andrew, 27 Roselea Drive, Dennistoun, Glasgow.
1883. Brown, George S., B.Sc., 19 Windsor Street, Glasgow.
1892. Brown, John Arthur, Dowanhill Gardens, Glasgow.
1890. Brownlie, Robert, 8 Ardgowan Terrace, Sandyford, Glasgow.
1894.*Bryden, Robert A., 212 St. Vincent Street, Glasgow.
1877. Buchanan, John, 230 Duke Street, Glasgow.
1888. Burnet, J. M., Duncairn Villa, Crosshill, Glasgow.
1866. Burnet, John, St. Kilda, Dowanhill, Glasgow.
1894. Burnet, John James, A.R.S.A., 18 University Avenue, Glasgow.

1877. Campbell, John MacNaught, Kelvingrove Museum, Glasgow.
1880. Carmichael, Robert S., Audit Office, St. Enoch Station, Glasgow.
1896. Carrick, Edward, Umtale, Mashonaland, South Africa.
1891. Carson, John, 12 Colebrooke Terrace, Glasgow.
1895.*Cassells, John, 62 Glencairn Drive, Pollokshields, Glasgow.
1895. Chalmers, David, 6 Raeberry Street, Glasgow.
1892. Cherry, James S., Trefoil Avenue, Shawlands, Glasgow.
1875.*Clavering, Thomas, 27 St. Vincent Place, Glasgow.

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Year of Election.

1894. Cooke, L. H., 18 Leven Street, Pollokshields, Glasgow.
1896. Cousar, John, 81 Hope Street, Glasgow.
1891. Cowie, Charles R., Woodend, Partick.

1877.*Dansken, John, 241 West George Street, Glasgow.
1874. Darling, George E., 178 St. Vincent Street, Glasgow.
1881. Dickson, John, 196 Parliamentary Road, Glasgow.
1894. Dixon, Walter, 164 St. Vincent Street, Glasgow.
1883.*Dobbie, Charles Lizars, 21 St. James Street, Hillhead, Glasgow.
1893. Donochy, John, 57 Hope Street, Glasgow.
1881.*Dougan, John, 13 Leven Street, Pollokshields, Glasgow.
1889. Douglas, William, Golconda, Kilwinning.
1888. Dow, Walter, Bekeni, Dalziel Drive, Pollokshields, Glasgow.
1887. Dow, William, 165 Hospital Street, Glasgow.
1867. Drew, Alexander, Creggandorroch, Blairmore.
1895. Dron, R. W., M.E., 79 West Regent Street, Glasgow.
1883. Dunlop, Robert, Whiterigg, Airdrie, *Vice-President.*
1868. Dunn, William, 183 West George Street, Glasgow.

1872.*Farquhar, Ex-Bailie John, 13 Belhaven Terrace, Hillhead, Glasgow.
1895. Fingland, Mrs., 15 Broomhill Avenue, Partick, Glasgow.
1895. Forbes, Alexander, 4 Killock Place, Ayr.

1866. Gale, James M., C.E., Corporation Water Works, Glasgow.
1892. Gardner, Alexander, 209 St. Vincent Street, Glasgow.
1887. Gardner, John, 21 Clyde Place, Glasgow.
1893. Gemmell, Mathew, 160 Bath Street, Glasgow.
1894.*Gilfillan, William, 129 St. Vincent Street, Glasgow.
1884. Gill, Robert, 63 West Regent Street, Glasgow.
1878.*Gilmour, Thomas, M.D., Port Ellen, Islay. [1873]
1895. Glen, Alexander, 25 Dumbreck Road, Glasgow.
1894.*Goldie, James, 40 St. Enoch Square, Glasgow.
1894. Goold, George Smeaton, 19 Blythswood Drive, Glasgow.
1895. Gow, John Robertson, 12 Renfield Street, Glasgow.
1877. Graham, M. M., 21 Bath Street, Glasgow.
1866. Grant, James, 8 Queen's Terrace, Glasgow.
1881. Gray, Harry, 15 Newton Terrace, Glasgow.
1886. Guy, Robert, 120 West Regent Street, Glasgow.

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Year of Election.

1890. Hair, William B., 41 Robertson Street, Glasgow.
1872. Hamilton, Archibald, C.E., Clyde Navigation Office, Robertson Street, Glasgow.
1880. Harvie, John, Clydesdale Bank, 30 St. Vincent Place, Glasgow.
1885. Henderson, George G., M.A., Andersonian Buildings, 204 George Street, Glasgow.
1880. Henderson, James, M.A., Whitehill School, Dennistoun, Glasgow.
1876. Henderson, John, Ravenscraig, Dumbreck, Glasgow.
1877. Hill, Thomas, N., 140 Bath Street, Glasgow.
1877. Hislop, George R., F.C.S., F.R.S.S.E., Corporation Gas Works, Paisley.
1891. Hodge, William, 27 Montgomerie Drive, Kelvinside, Glasgow.
1893. Hogg, R. M., Teacher, Irvine.
1894. Hubbard, John James, 25 Lilybank Gardens, Hillhead, Glasgow.
1894. Hubbard, Walter Raglan, 9 Broomhill Avenue, Partick, Glasgow.
1866. Hunt, Edmund, C.E., 87 St. Vincent Street, Glasgow.

1893. Innes, Peter, 5 Ibrox Place, Paisley Road, W., Glasgow.

1890. Johnstone, Ronald H., C.E., 75 West Nile Street, Glasgow.
1884. Jolly, William, F.R.S.E., F.G.S., Greenhead House, Govan.

1870.*Ker, William, 1 High Windsor Terrace, Glasgow.
1890. Kidston, Robert, F.G.S., 24 Victoria Place, Stirling.
1877. Kincaid, Thomas, 9 Lansdowne Crescent, Glasgow.
1882. King, Hugh B., Kilwinning, Ayrshire.
1882. King, Robert C., C.A., Kilwinning, Ayrshire.
1860. Kirsop, John, 98 Argyle Street, Glasgow.
1894. Knight, Rev. G. A. Frank, M.A., 11 South Park Terrace, Hillhead, Glasgow.
1867. Knox, Adam, 10 Clayton Terrace, Dennistoun, Glasgow.
1872. Knox, John, 58 Bath Street, Glasgow.

1892. Laird, Alexander, 63 Wilson Street, Glasgow.
1883. Laird, Andrew, C.E., 123 St. Vincent Street, Glasgow.
1880. Lucas, William, 133 West George Street, Glasgow.
1892. Lusk, Hugh D., Rosebank, Forsyth Street, Greenock.

1894. M'Ara, Alexander, 27 India Street, Glasgow.
1866. M'Clelland, Andrew S., C.A., 115 St. Vincent Street, Glasgow.
1895. M'Coll, Archibald, Slate Quarry Manager, Ballachulish

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Year of Election.

1895. M'Connell, Alexander, C.E., 167 St. Vincent Street, Glasgow.
1896. M'Cowan, Donald, Dundashill House, Port-Dundas, Glasgow.
1889. M'Creath, George W., M.E., 208 St. Vincent Street, Glasgow.
1893.*M'Crie, George, 16 Sardinia Place, Hillhead, Glasgow.
1884. M'Donald, A. B., C.E., 64 Cochrane Street, Glasgow.
1892. M'Farlane, John R., 22 Royal Exchange Square, Glasgow.
1894.*M'Gilvray, Robert Alexander, 129 West Regent Street, Glasgow.
1867. M'Glashan, John, 114 Candleriggs, Glasgow.
1893. M'Innes, William A., 20 Dixon Avenue, Govanhill, Glasgow.
1882. Macintosh, Rev. John, The Manse, Uddingston.
1894. Mackie, John, M.E., Crofthead, Neilston.
1886. M'Laren, Robert, Bonny, Gardenside, Uddingston.
1881.*Maclay, David J., 3 Woodlands Terrace, Glasgow.
1894. Maclay, James, 169 West George Street, Glasgow.
1877. Maclay, William, 7 Eildon Villas, Mount Florida, Glasgow.
1882. M'Lennan, James S., Oswald Public School, Jordanhill, Glasgow, *Hon. Librarian.*
1895. M'Nair, Peter, 16 Martyr Street, Glasgow.
1883. M'Whirr, John, 10 Kilmailing Terrace, Cathcart.
1887. Main, John, F.G.S., 21 Hartington Gardens, Dowanhill, Glasgow.
1895. Manners, Hugh, Airdrie Academy, Airdrie.
1874. Marshall, Robert, 97 Wellington Street, Glasgow.
1887. Meiklejohn, Andrew, 3 Windsor Street, Glasgow.
1867. Millar, John (J. Black, Drew & Co.), 23 Royal Exchange Square, Glasgow.
1877. Millar, W. J., C.E., 145 Hill Street, Garnethill, Glasgow.
1892. Miller, William, Clyde Street, Motherwell.
1881. Mitchell, G. A., 63 Bath Street, Glasgow.
1877. Moore, Robert T., B.Sc., C.E., 156 St. Vincent Street, Glasgow.
1885. More, Robert, 505 Sauchiehall Street, Glasgow.
1889. Motherwell, A. B., British Linen Bank, Airdrie.
1859. Murdoch, James Barclay, F.R.Ph.S.E., Capelrig, Mearns, Renfrewshire, *Honorary Secretary.*
1894.*Murdoch, Robert, 19 Commerce Street, Glasgow.
1870.*Murray, David, LL.D., 169 West George Street, Glasgow.

1865. Napier, J. W., Woodielea, 14 Windsor Circus, Glasgow.
1891. Neilson, James, Milnbank House, Dennistoun, *Vice-President.*
1894.*Neilson, James, 116 Bishop Street, Port-Dundas, Glasgow.

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Year of Election.

1868. Neilson, Richard, 33 Virginia Street, Glasgow.
1894. Niven, Thomas Ogilvie, 131 West Regent Street, Glasgow.

1869. Orr, John, 12 Newhall Terrace, Glasgow.

1875. Pearson, David, 15 Carnarvon Street, Glasgow.
1891. Pollock, Arthur, Kirkland, Bonhill, Dumbartonshire.
1877. Pratt, Gavin M., 3 Ralston Terrace, Temple, Glasgow, *Assistant Hon. Secretary.*

1873. Rankine, David, C.E., 238 West George Street, Glasgow.
1880. Reid, James A. (of M'Grigor, Donald & Co.), 172 St. Vincent Street, Glasgow.
1896. Reid, Rev. William, F.C. Manse, Hurlford, Kilmarnock.
1874. Renwick, John, Blacklands, Maryhill.
1877. Rhind, John, 82 Hill Street, Garnethill, Glasgow.
1894. Ross, Andrew, 12 Ann Street, City, Glasgow.
1878. Ross, David, LL.D., 47 Carnarvon Street, Glasgow.
1875.*Rottenburg, Paul, Holmhurst, Dowanhill Gardens, Glasgow.
1865. Rowan, David, 22 Woodside Place, Glasgow.

1893. Sexton, Prof. A. Humboldt, 204 George Street, Glasgow.
1891.*Sharp, John Grant, 127 Great Hamilton Street, Glasgow.
1889. Simpson, Rev. Alexander, B.A., B.Sc., F.G.S., 46 Prince's Square, Strathbungo, Glasgow.
1888. Sinclair, Thomas, 206 New Dalmarnock Road, Glasgow.
1887. Sinclair, William, Grange, Bothwell.
1889. Sloan, Samuel, M.D., 5 Somerset Place, Sauchiehall Street, Glasgow.
1871.*Smellie, Thomas D., 213 St. Vincent Street, Glasgow.
1895. Smith, Rev. Frederick, The Limes, Dunblane, Perthshire.
1891. Smith, James Parker, M.P., Jordanhill, Partick.
1865. Smith, John, Monkredding, Kilwinning, Ayrshire.
1887. Somerville, Rev. James E., B.D., Castellar, Crieff, Perthshire.
1871. Sommerville, Joseph, 45 Montgomerie Street, Kelvinside North, Glasgow.
1896. Stark, James, 10 Hillend Gardens, Partick.
1881. Steel, James, 14 Shamrock Street, Glasgow.
1884. Steele, Robert Innes, 3 Nithsdale Place, Pollokshields, Glasgow.
1893. Steele, William, 12 Wendover Crescent, Mount Florida, Glasgow.
1880. Stewart, James, Williamwood, Cathcart.

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Year of Election.

1878. Stewart, Thomas, Hydraulic Engineers' Department, Capetown, South Africa.
1891. Stirling, David, 49 Jamaica Street, Glasgow.
1895. Styles, Oliver, 105 Buccleuch Street, Glasgow.

1893. Taylor, Henry, 20 Campbell Street, Maryhill.
1895. Thompson, George R., 207 George Street, Glasgow.
1894. Thomson, William Brown, Banker, Wishaw.
1895. Thomson, William S., 4 Santa Margarita, Corunna, Spain, c/o William Morrison, Bent View, Burnblae Park, Hamilton.
1885. Tullis, David, Glencairn, Burnside, Rutherglen.
1885. Tullis, James T., The Anchorage, Burnside, Rutherglen.

1895. Watt, Hugh Boyd, 101 St. Vincent Street, Glasgow.
1874. White, James, 93 North Frederick Street, Glasgow.
1880. Whitelaw, Thomas, Coalmaster, Motherwell.
1896. Whyte, Adam Gowans, 1 Holyrood Quadrant, Glasgow.
1874. Whyte, John, 7 Stuart Street, Shawlands, Glasgow.
1866. Wight, John, C.A., 150 Hope Street, Glasgow, *Hon. Treasurer.*
1895. Wise, John, 170 Bellfield Street, Glasgow.
1881. Wotherspoon, David, 130 Dumbarton Road, Glasgow.

1896.*Young, James, jun., Caerleon, Bearsden, Glasgow.
1869.*Young, John, LL.D., F.G.S., Hunterian Museum, University of Glasgow. [1859]

Note.—The names of Life Members have an asterisk (*) prefixed. If Ordinary Members previously, the date of the original election is placed after the name, in brackets ([ ]).

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PUBLICATIONS.

TRANSACTIONS.

Demy 8vo.

Vol. I., Part 1.—The Geology of the Campsie District, By John Young, LL.D., F.G.S. (3rd edition, revised), 2/
———— Part 2.—The Phenomena of the Glacial Drift of Scotland. By Sir Archibald Geikie, F.R.S. (*Reprint*), - 5/
Vol. II., Part 1.—Papers on Local and Theoretical Geology, - - 4/6
———— Part 2.— Do. do. do., (*Out of Print*).
———— Part 3.— Do. do. do., - - - 4/6
Vol. III., Part 1.— Do. [contains "On Geological Time." By Lord Kelvin, F.R.S.], - - - 4/
———— Part 2.— Do. [contains "On Geological Dynamics." By Lord Kelvin, F.R.S.], - - 4/
———— (Supplement)—On the Carboniferous Fossils of the West of Scotland. By John Young, LL.D., F.G.S., and James Armstrong, - - - - - 4/
Vol. IV., Part 1.—Papers on Local and Theoretical Geology, - - 3/
———— Part 2.— Do. do. do., - - 3/
———— Part 3.— Do. do. do., - - 3/
Vol. V., Part 1.— Do. do. do., - - 4/
———— Part 2.— Do. [contains "Geological Climate." By Lord Kelvin, F.R.S.], - - - 4/
Vol. VI., Part 1.— Do. [contains "The Internal Condition of the Earth." By Lord Kelvin, F.R.S.], 4/
———— Part 2.—Papers on Local and Theoretical Geology, - 4/
Vol. VII., Part 1.— Do. do. do., - 5/
———— Part 2.— Do. do. do., - 5/
Vol. VIII. Part 1.— Do. do. do., - 5/
———— Part 2.— Do. [contains "Polar Ice Caps and their Influence in changing Sea Levels." By Lord Kelvin, F.R.S.], - - - - 5/
Vol. IX. Part 1.—Papers on Local and Theoretical Geology, - 6/6
———— Part 2.— Do. do. do. - 6/6
Vol. X. Part 1.— Do. do. do. - 6/6
———— Part 2.— Do. do. do. - 7/
Vol. XI. Part 1.—In the Press.

Palæontological Series.

Demy 4to.

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Catalogue of Western Scottish Fossils.

By James Armstrong, John Young, LL.D., F.G.S., and David Robertson, F.L.S., F.G.S., compiled for the Meeting of the British Association, Glasgow, 1876 (and incorporating the Supplement to Vol. III. of the *Transactions*). Small 8vo, cloth, 2/6
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The Geology of the Campsie District.

By John Young, LL.D., F.G.S. (forming Part 1, Vol. I., of the *Transactions*). Third edition, 1894. Demy 8vo, paper boards, - 2/

The Phenomena of the Glacial Drift.

By Sir Archibald Geikie, F.R.S. (*Reprint.*) Demy 8vo, paper boards, 5/

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ERRATA.

Page 23.—In the Appendix to Mr. Bell's paper "On the Origin of Certain Granite Boulders in the Clyde Valley," the 5th line, "*Loch Long*, about 10 or 12 near the head of the Loch," should read "*Loch Goil*," &c.

Page 29.—Some few copies of "The Section from Shewalton Moor to Ardeer Sandstone Quarry" illustrating Mr. Smith's paper on "The Geological position of the Irvine Whale Bed" have the Vertical Scale given as 1 *inch to* 16 *feet*. This is the Scale of the original drawing, while the reduced Section is on the Scale of 1 *inch to* 42 *feet*.

Correct copies of the Section may be had from the Hon. Secretary.

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